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THE

POPULAR SCIENCE MONTHLY.

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WHAT AMERICAN ZOÖLOGISTS HAVE DONE FOR EVOLUTION.[1]

By Professor EDWARD S. MORSE.

I.

IT would be pleasant indeed if only a lecture or an essay were expected from the presiding officer of the Section; but an address implies a great deal more, and the giver of it is not only expected to be entertaining, where perhaps he never entertained before, but instructive upon grounds upon which, perchance, he has made but partial survey. Among the many questions of sustaining interest, a number of subjects intrude themselves. A general review of the work accomplished since the last meeting of the Association would seem an appropriate subject for discourse. Yet beyond my special studies I feel quite incompetent to scan so broad a field. In this year of Centennial reviews, one might naturally fall into an attempt to sketch the growth of science and the work accomplished within the last hundred years, but that would not only be too vast a field, but would on the whole be unprofitable, since time-boundaries, like the surveyor's lines bordering a State, have no definite existence in Nature. The natural boundaries of oceans and sierras do indeed isolate and impress peculiarities of thought and action upon man, as upon the creatures below him, and for this reason we may with propriety examine the work of our nation in any line of investigation. Never before has the study of animals been raised to so high a dignity as at present. While chemistry could point to its triumphs in the arts, and geology to the revelations of hidden wealth in the rocks, zoölogy was for the most part a mere adjunct to geology, or a means to thwart the

[1] An address delivered at the meeting of the American Association for the Advancement of Science. Read at Buffalo, New York, August, 1876. By Edward S. Morse, Vice-President Biological Section.

ravages of insects. Now, however, it is the pivot on which the doctrine of man's origin hinges. The worlds themselves are too old to study, though the spectroscope reveals the existence of celestial protoplasm as their physical basis. The rocks are too rigid and the time too immense to come within the compass of our minds, but the living facts of evolution are with us to-day in these graceful forms and their constant changes, while the records more or less preserved in past times give us a clew to things hinted at in the earlier changes of present existing forms. It seems, therefore, at the present time, that a review of the work accomplished by American students for the doctrines of natural selection might be acceptable for several reasons, and first among them might be mentioned the fact that thus far no general review of the kind has been made; and, secondly, that with few exceptions all the general works upon the subject are from English or German sources, and filled with the results of work done there oftentimes to the exclusion of work done elsewhere. The oft-repeated examples in support of the derivative theory belong to Europe. The public are familiar with these facts only, and come naturally to believe that these examples alone exist, and from their remoteness do not carry the weight of equally or perhaps more suggestive facts which lie concealed in the technical publications of our own societies. A review of the work accomplished by American students bearing upon the doctrine of descent must of necessity be brief. Even a review of a moiety of the work is beyond the limits of an address of this nature. And for obvious reasons I must needs here restrict it to one branch of biology, namely, zoölogy. For material, the scientific publications of the country have been scanned, and an attempt has been made to bring together the more prominent facts bearing upon natural selection. In this review the zoölogical science of the country presents itself in two distinct periods: The first period, embracing as to time-limits the greatest portion, may be recognized as embracing the lowest stages of the science; it included among others a class of men who busied themselves in taking an inventory of the animals of the country, an important and necessary work to be compared to that of the hewers and diggers who first settle a new country, but in their work demanding no deep knowledge or breadth of view. And so the work to be done in tabulating the animals has more often been done by specialists who neither knew nor cared to know the facts lying beyond the limits of their studies; a work often prompted by the same spirit that one sees among children in the collection of birds'-eggs and postage-stamps. The workers in this class were compared by Agassiz to those who make the brick and shape the stone for the edifice, an indispensable work, but with it was raised not the edifice but an almost insuperable barrier against the acceptance of views more in accordance with reason and common-sense. So thoroughly interwoven with this work were certain conceptions believed to be infallible, that overpowering

indeed has been the argument to render as coadjutors the very men who so thoroughly opposed Darwin at the outset. It seems unnecessary to point out the mode of work adopted by the class above described. Their honor involved as soon as their name had been attached to a supposed new species, and any deviation from the type oftentimes persistently overlooked, what wonder, when every local variety received a new name and that name stamped upon a supposed valid creation—what wonder, I repeat, that whole groups of animals have been so thoroughly scourged by such work that few have the courage to engage in the task of revision?

Emerson's reflections on the science of England in 1847 would apply with far more propriety to our country even at a much later date, where in his words "one hermit finds this fact and another finds that, and lives and dies ignorant of its value." With the noble examples of Dana, Wyman, Leidy, and Burnett, before them, they did not profit. In fact, the labors of these honored men, and early in the century Lesueur and others, gave the country its largest claim to recognition abroad. The second period dates from the advent of Agassiz in this country. With his presence a gradual but entire change took place. He rendered the study a dignity rather than a pastime. No longer were the triflers to fling their loose work before the academies unrebuked. The protests he uttered in this Association were the means of elevating the tone of the communications. In fact, nothing indicates the poverty of our attainments in zoölogy more than an examination of the volumes preceding Agassiz's presence and the succeeding volumes. With his honest repudiation of all that was bad, he frightened away the lighter chaff, and there was but little solid work left to take its place. Agassiz made men, and his example, and the methods of work taught by him, spread to other parts of the country. He brought the American student into intimate acquaintance with the classical work of European naturalists. In his public lectures the names of Cuvier, Von Baer, Leuckart, and others, became familiar. The public caught the enthusiasm of this great teacher, and money was lavishly given by the citizens and the State in aid of his scientific undertakings. Agassiz's earnest protest against evolution checked the too hasty acceptance of this theory among American students. But even the weight of his powerful opposition could not long retard the gradual spread of Darwin's views; and now his own students, last to yield, have, with hardly an exception, adopted the general view of derivation as opposed to that of special creation. The results of his protest have been beneficial in one sense. They have prompted the seeking of proofs in this country, and now our students are prepared to show the results of their work in evidence of the laws of progressive development, and it is mainly this work that I wish to review. So much is claimed for birthplace that, in the way of history, it may not be amiss to call attention to

the fact that the first clear premonition of the theory of natural selection came from this country.

William Charles Wells, born in this country, at Charleston, South Carolina, in 1757, in a paper read before the Royal Society, in 1813, first substantially originated the theory to account for the black skin of the negro. He limits his application to races of men and certain peculiarities of color, correlated with an immunity from certain diseases; in proof of it he cites domesticated animals, and the selection by man in precisely the same line of argument urged by Darwin. In the preface to the last edition to the "Origin of Species," Darwin refers to Wells's essay as entitled to the credit of containing the earliest known recognition of the principle. Dr. Wells first shows that varieties among men as among animals are always occurring, and having cited the way in which man selects certain qualities among domesticated animals and thus secures different breeds, calls attention to the well-known fact that the black as well as the white races are differently affected by certain diseases of the countries which they inhabit. He finds a coincidence between the immunity from certain diseases and the black color of the skin, though why this is so he does not attempt to explain. He thinks that, through the successive survival of dark skins, the dark variety of the human race has become fixed. Referring to the man's selective action regarding domesticated animals, he says: "But what is here done by art seems to be done with equal efficacy, though more slowly, by Nature, in the formation of varieties of mankind fitted for the country which they inhabit." These sentences have such a Darwinian sound that, when we remember they were dragged from obscurity by Mr. Darwin himself, we can share in what a recent writer[1] happily calls "Mr. Darwin's evident delight at discovering that some one else had said his good things before him, or has been on the verge of uttering them." As early as 1843, Prof. Haldeman[2] discussed some of the arguments brought forward by the opponents of the Lamarckian theory, and offered certain views in favor of the transmutation of species. While he does not hint at the laws of natural selection, he recognizes fully the value of varieties and their persistency and ultimate divergence. He says, "Although we may not be able artificially to produce a change beyond a given point, it would be a hasty inference to suppose that a physical agent acting gradually for ages could not carry the variation a step or two farther, so that instead of the original one we will say four varieties, they might amount to six, the sixth being sufficiently unlike the earlier ones to induce a naturalist to consider it distinct."

In the year 1850, Dr. Joseph Leidy, in a paper on entophyta in living animals, wrote as follows: "The essential conditions of life are

[1] Gray's "Darwiniana," p. 284.

[2] *Journal of the Boston Society of Natural History*, vol. iv., p. 368.

five in number, namely: a germ, nutritive matter, air, water, heat, the four latter undoubtedly existing in the interior of all animals."[1] Dr. Leidy affirms his belief that very slight modifications of these essential conditions of life were sufficient to produce the vast variety of living beings upon the globe. The theory of derivation based upon the principles of natural selection demands the following admissions: that species vary, that peculiarities are transmitted or inherited, that a greater number of individuals perish than survive, and that the physical features of the earth are now and have been constantly changing, and that precisely the same conditions never recur. These are admitted facts. Now comes the theoretical part of natural selection, namely, that the varieties which survive are those which are more in harmony with the environments of the time. These propositions, with minor ones, form the theory of Darwin. Lamarck and others had recognized the gradual enhancement of varieties into species, but had not struck the key-note of natural selection, though Wells in the beginning of the century had clearly recognized it in a pertinent example. If we look impartially at these propositions, we need no demonstration to prove the inheritance of characters the most minute, and even the perpetuation of the most subtile features.

On general principles, too, the proposition, that those individuals best adapted to their surroundings survive, need only be stated to be accepted by a reasonable mind. In truth, to deny it would be to deny, as Alphonse de Candolle says, that a round stone would roll down-hill faster and farther than a flat one. Indeed, this eminent botanist affirms that natural selection is neither a theory nor an hypothesis, but the explanation of a necessary fact. The constant physical changes in the past and present condition of the world are incontrovertibly established. It seems, then, that the prime question resolves itself into whether each species as a whole has something inherent which prompts it to vary irrespective of its environments, or whether a correlation can be established between the variation of species and certain physical conditions inducing these variations, and here let me add that of all groups of animals from species through genera to higher divisions, that group of individuals recognized as a species has the most tangible existence. And, as a proof of this, there need only be mentioned the fact that many naturalists, while regarding species as clearly distinct, have on the other hand looked upon classification as an artificial method to facilitate the study, and hence the innumerable schemes and the successive interpolation of sub-classes, sub-orders, sub-families, and sub-genera, which simply circumscribed smaller proofs than had before been recognized.

The rapid multiplication of some of these groups has already formed a serious obstacle to the study of systematic zoölogy.

What would good Dr. Mitchell have said if he could have foreseen

[1] "Proceedings of the Philosophical Academy," vol. iii., p. 7.

the generic lists of to-day! In an article on the "Proteus of Lake Erie," he expressed his aversion to multiplying names in zoölogy, and lamented the tendency. He protested as follows, fifty years ago: "By some, these innovations have been so wantonly introduced, as almost to threaten in the end the erection of every species into a distinct genus."[1] Though these words were undoubtedly aimed at Rafinesque, they were none the less prophetic. Whatever may be said of the existence in nature of other groups, there can be no question that species have the most definite existence, and it would seem then that nothing more need be proved for the theory of descent as opposed to the theory of special creation, than the establishment of the fact that species assume the characters of new species, or disappear altogether with a change of surroundings. As examples might be cited, the transplanting of Alpine seeds to warmer regions below, and an accompanying change of the plant into another species before known in the warmer region, or, more remarkable still, the change of a species of *Crustacean* which lives in salt water, to another species with a partial freshening of the water, and this freshening slowly persisted in, the form changing into another genus, and in so doing losing one of its segments. In the first case we see the effect of temperature, and in the second case the physical influence of salt and water in different proportions.

Now, these and hundreds of similar examples can be incontestably proved.

Even the prolonged existence of the form of some animals, like *Lingula*, may be referred to an inherent vitality which enables them to survive changes that caused the death of thousands of others.

In an early discussion of Darwin's theory,[2] Prof. Agassiz cited the persistence of *Lingula* as fatal to the theory, and Prof. William B. Rogers replied that the vital characters of some animals would enable them to survive above others. Ten years later, I had an opportunity of studying living *Lingula* on the coast of North Carolina, and brought specimens home alive in a small jar of water, and kept them in a common bowl for six months without the slightest care. Their power of surviving under changed conditions—their vitality, in other words—seems incredible.[3] (For further details, *see* reference below.)

It has for a long time been suspected that the species of *Mollusca*, described in such profusion in this country, would be reduced when the slightest attention to their habits had been made. Dr. James Lewis[4] long ago observed that a certain species of fresh-water mussel, described as *Alasmodonta truncata*, is only the truncate form of another species, *A. marginata*. From a careful study of the condi-

[1] *American Journal of Science and Arts*, vol. vii., 1829.

[2] "Proceedings of the Boston Society of Natural History," vol. vii., p. 231, December 15, 1860.

[3] Ibid., vol. xv., p. 315.

[4] Ibid., vol. v., p. 121.

tions surrounding the first form in the Mohawk River, he had reason to believe that the rapid currents which pass over it bear along substances that, coming in contact with the exposed edges of the shell, break them down, thus retarding the growth of the shell at this point, and the animal concentrates its growth-powers to the repairs of the broken portion. The same gentleman also shows that the so-called species *Lymnæa elodes*, *catascopium*, and *marginata*, "are modifications of one type or species, influenced by locality and temperature varying the method of development." [1]

A. G. Wetherby [2] calls attention to the variation in form of a group of fresh-water snails, found in the greatest abundance in certain streams of Tennessee and North Alabama. In showing the varied influences they are subjected to he cites the rapid currents of the channels, and the greater liability of the snails being torn from the rocks. He shows that they are exposed in various ways to the effects of these currents, with all their changing impetus of high and low water—exposed also to privation of food from the scouring sand removing the confervæ, upon which they subsist, from the rocks. He takes into account temperature, chemical action, and the like, and says, "No greater vicissitude can be imagined than this growth in an unstable element." Coincident with these diverse conditions he finds an enormous variety of forms, and frankly acknowledges that many of those described as distinct species must be reduced to synonyms.

George W. Tryon, in his large work on the American Melanians, published by the Smithsonian Institution, having finished his manuscript in 1865, says, under date of 1873, when the work was finally published, "A more enlarged acquaintance with fresh-water shells convinces me that a much greater reduction of the number of species than I have attempted must eventually be made."

If we now look upon the definition of a species, as given by a gentleman foremost in the ranks as a describer of species, we find it formulated as follows: A species represents "a primary established law, stamped with a persistent form (a type) pertaining solely to itself, with the power of successively reproducing the same form, and none other;" and this gentleman has not hesitated to base these "primary organic laws" upon the evidence of a single specimen, and in some cases even the fragments of one have offered him a sufficient inducement!

But it has been argued by some that a wide variation may be the case with many species. Prof. Agassiz,[3] at a meeting of the American Academy, reiterated his opinion that what are called varieties by naturalists do not in reality exist as such. He found a great abundance of diverging forms in Echinoderms, which, without acquaintance

[1] "Proceedings of the Boston Society of Natural History," vol. v., pp. 121–128.

[2] *Proceedings of Cincinnati Society of Natural Science*, No. 1, June, 1876.

[3] "Proceedings of the American Academy," vol. v., p. 72.

with connecting ones, would be deemed distinct species, but he found they all passed insensibly into each other.

Prof. Parsons suggested that more extended observations might connect received species by intermediate forms, no less than so-called varieties; and Prof. Gray remarked that the intermediate forms, connecting by whatsoever numerous gradations the strongly divergent forms with that assumed as a type of a species, so far from disproving existence of varieties, would seem to furnish the best possible proof that these were varieties. Without the intermediate forms they would, it was said, be taken for species; their discovery reduced them to varieties, between which (according to the ordinary view), intermediate states were to be expected.

Recognizing, then, the existence of varieties, and of varieties sufficiently pronounced to have led careful naturalists to regard them as distinct species, what shall we say when it is found that these marked forms are correlated with certain physical conditions, many of which have originated within comparatively recent times? Dr. J. G. Cooper,[1] after a careful study of the California land snails, ascertained that "species, sub-species, and varieties, living in cool, damp situations, become more highly developed (but not always larger) than the others; the shell assuming a more compact (imperforate) form, and losing those indications of immaturity referred to, viz., sharp, delicate sculpture, bristles, and angular periphery. These characteristics, however, remain more or less permanently for indefinite periods, and give that fixedness to the various forms, even when living under the same conditions, which enables us to retain them as sub-species differing from varieties in permanency, and from races in not inhabiting distinct regions." It may be added that Stearns, Bland, and Binney, have likewise observed the same peculiar variations associated with aridity.

In a broader field, and compassing different classes, Prof. Spencer F. Baird, Mr. J. A. Allen, and Mr. Robert Ridgway, have severally shown that marked and specific changes are seen in birds and mammals corresponding to differences in their surroundings. Prof. Baird, in a paper entitled "The Distribution and Migration of North American Birds,"[2] has shown that birds in high altitudes and those bred at the North are larger than those born South and at low altitudes; that Western birds of the same species have longer tails than eastern examples, and that the bill increases in size in those birds occurring in Florida as compared with those found north of that State, and that on the Pacific coast the birds are darker in color than those found in the interior.

Mr. J. A. Allen[3] has made a more special study of this matter, and

[1] "Proceedings of the California Academy of Natural Science," vol. v., p. 128.

[2] *American Journal of Science and Arts*, vol. xli., January and March, 1866.

[3] "Proceedings of the Boston Society of Natural History," vol. xv., p. 156.

his work ranks among the most important contributions to this science. Mr. Allen finds that there are marked geographical variations in mammals and birds. He shows that northern mammals of the same species are more thickly and softly furred, and that toward the south the peripheral parts, such as the ears and feet, are more developed. The same law holds good in birds, a diminution in size being observed toward the south, and the individuals being darker in color.

As one goes south he meets with the same species of birds, whose bodies are shorter, but whose beak, tail, and claws, are longer. On the Plains, also, he found the birds with plainer tints, while southward the colors became more intense. On drawing up a table indicating the regions of lighter varieties, and comparing it with a chart of mean annual rainfall, Mr. Allen found the lighter forms occurred in dry regions, and the dark forms in relatively humid regions. To sum up: Mr. Allen finds in latitudinal variation climatic influences affecting color as well as altering the size of bill, claw, and tail, while longitudinal variation usually affects color alone.

He states that these laws are now so well known that a species may be predicted to assume a given color if under certain specific climatic conditions.

Mr. Robert Ridgway [1] has in a similar way called attention to the relation between color and geographical distribution in birds as exhibited in melanism and hyperchromatism, and has shown that red areas "spread" or enlarge their field in proportion as we trace certain species to the Pacific coast, and that in the same proportion yellow often intensifies in tint.

The results of these investigations can be easily understood. Nearly if not quite one hundred and fifty species of birds, which were recognized as distinct, are at once reduced to varieties, though less than twelve years ago they were looked upon as good species, with which no external influence had anything to do. Nearly if not quite a fifth of the number of species of birds have been reduced by the investigations of Baird, Allen, Coues, and Ridgway.

The mammals, through the same study of geographical variation, will have been reduced at least one-fourth. Already Mr. Allen [2] has studied the geographical variation of the squirrels, and the result is that a reduction has been made of one-half the number of species before recognized. Prof. Baird, in his monograph of North American squirrels, reduced the number from twenty-four, as acknowledged by Audubon and Bachman, to ten well-established species and two doubtful varieties. Allen, with still greater advantage in the shape of a mass of material from the Western surveys, reduced the ten species to five species, with seven geographical varieties.

[1] *American Journal of Science and Arts*, vol. iv., December, 1872, p. 454, and vol. v., p. 39.

[2] "Proceedings of the Boston Society of Natural History," vol. xiv., p. 276.

Should it be urged that the present tendency toward reducing species be taken as an evidence that species had not before been properly defined, then it offers a stronger argument still in favor of the fact that species are even more variable than had before been supposed, leaving the greater possibility of larger numbers of these ultimately surviving. Again, the assumption that the limitation of specific variation had not been properly indicated, shows how reprehensible has been the work of some of those who have burdened our literature with their bad species.

The fact is, the work has in a measure been justifiable, and is not to be wholly condemned. The workers in this line have followed the teachings of their masters. A group of individuals removed from an allied group of individuals by an extra dot or darker shade, perpetuating their kind from generation to generation, marked with persistent characters, and in every way coming up to the standard recognized as specific, had the right to be judged as such. It is only when a whole series of forms are collected, and climatic influences are seen to affect these in the same way that they affect other groups of species even in different classes, that the mere influence of moisture and temperature is shown to be the sole cause of many of these supposed specific characters.

Dr. A. S. Packard, in his remarkable monograph of a group of moths, the *Phalænidæ*, published under the auspices of the Hayden Survey, finds that with some species there are changes analogous to those pointed out by Baird and Allen; and while he does not find enough to establish a law, yet to his mind enough is seen "to illustrate how far climatic variation goes as a factor in producing primary differences in faunæ within the same zones of temperature," and he admits that varietal and even specific differences may arise from these climatic causes alone. Dr. Packard, in the same work, under the head of "Origin of Genera and Species," says, "The number of so-called species tends to be reduced as our specimens and information increase." The genera also "are as artificial creations as species and varieties. The work of the systematic biologist often amounts to but little more than putting Nature in a strait-jacket."

An application of the influence of temperature is here proper, as explaining, on a rational ground, the persistence of peculiar arctic forms of animals and plants on the summits of Mount Washington and other high peaks. With a knowledge of glacial phenomena, we are capable of judging the condition of things which must, of necessity, have existed directly after the recedence of the great ice-sheet: its southern border slowly retreating, and, with the encroachment of the warmer zone, the arctic forms dying out, or surviving under changed conditions; but, in high plateaus and mountains, local glaciers flourished for a while, and at their bases arctic forms flourished, and, lingering too long, were ultimately cut off by the retreat

of the main field. This interpretation of arctic forms on high peaks, though attended to by several American naturalists, is not new. Oswald Heer, in discussing the origin of certain animals and plants, coincides with De Candolle that Alpine plants are relics, as it were, of a glacial epoch. Prof. Gray[1] had also independently arrived at the same conclusions, based on a comparison of the plants of Eastern North America and Japan. In the position he maintained regarding the derivation of species from preëxisting ones, he stood far in advance of his brother naturalists in this country, for this was before Darwin's great work had appeared, and before Heer had developed the host of fossil plants from the arctic zone. Mr. S. I. Smith, in speaking of mountain faunæ, points out the gradual encroachment of glaciers, and the drawing down of northern forms; and, as the glaciers retreated, these forms were caught, "the mountain-summits being left as aërial islands." Dr. Packard and Mr. Scudder have severally called attention to the same thing.

Prof. A. R. Grote has more fully dealt with the subject in a paper read before this Association, and in a graphic way shows that the "former existence of a long and widely-spread winter of years is offered in evidence through the frail brown Œneis butterflies, that live on the top of the mountains within the temperate zone." I have been thus explicit, in order to contrast these more rational views with those formerly entertained by eminent naturalists, whose minds were imbued at the time with the idea of special creation. Mr. Samuel H. Scudder[2] read before the Boston Society of Natural History an account of distinct zones of life on high mountains, as illustrated in the insect-life of Mount Washington. He called attention to certain insects which he supposed peculiar to the summit, and not found farther north, though showing a remarkable correspondence to certain arctic forms. Prof. Wyman asked whether all the facts might not be accounted for on the theory of migration northward after a glacial epoch, and Prof. Rogers suggested that the facts might be accounted for on the migratory theory if we added thereto the supposition of subsequent variation induced by isolation. Yet these views were persistently opposed by the other naturalists present. The mass of evidence already contributed, as to the extraordinary variation in color, markings, and size of species coinciding with their physical surroundings, though perhaps trivial in itself, becomes important when the proofs are grouped together, and all bear upon the theory of derivation. So slight a thing as change of food is found to influence certain animals even to a degree usually regarded specific. The late Dr. B. D. Walsh[3] discovered some very curious features among in-

[1] "Memoirs of the American Academy," vol. vi., pp. 377–458 (1859).

[2] "Proceedings of the Boston Society of Natural History," vol. ix., p. 230.

[3] "On Phytophagic Varieties and Phytophagic Species," "Proceedings of the Entomological Society of Philadelphia," vol. iii., p. 403.

sects connected with a change of food. First, he established the fact that insects accustomed to one kind of plant could acquire a taste for another kind, and he has shown that in thus changing the food of the insect a change took place in the appearance of either the larva, pupa, or imago, and sometimes all three stages were affected. Dr. Fitch had observed that changing an insect's larva from the leaf to the fruit affected the appearance of the larva. It would be impossible to give even an abstract of Dr. Walsh's remarkable essay. It may be said, however, that his investigations led him irresistibly to the conclusion that the present species have been derived from preëxisting ones, and in numberless cases he is capable of showing the successive stages from the dawn of a plant-eating variety, where the changes are slightly seen in the larva only, to the plant-eating species in which profound changes are seen in the larva, pupa, and imago.

The minor factors of natural selection, such as protective coloring and mimicry, have been variously illustrated by Mr. R. E. C. Stearns, Dr. Kneeland, Prof. Cope, Dr. Charles C. Abbott, and others. In a special paper on "The Adaptive Coloration of Mollusca,"[1] I have endeavored to show not only a wide-spread application of this feature to mollusks, and especially those exposed by the tide, but in some cases a mimicry of inanimate objects, as the accumulation of clay or grains of sand upon the shell.

Wallace's theory of birds'-nests finds interesting confirmations in the observations of Dr. Abbott, who made a special study of a large number of robins'-nests, and found the widest variation among them. He studied also the nests of the Baltimore oriole, where, according to the theory of Wallace, a concealing nest should be made, the bird being exceedingly bright-colored. He found that, away from the habitations of man, the orioles built concealing nests; but in villages and cities, on the other hand, where they were in no special danger from predatory hawks, the nests were built comparatively open, so that the bird within was not concealed.[2]

The differences in the habits of animals of the same species are noticed in different parts of the country, and such facts militate against the idea that certain unerring ways were implanted in them at the outset. Indeed, such facts go to show that these various creatures not only become adapted to their surroundings, but that individual peculiarities manifest themselves. The observations of Dr. Coues, Mr. Allen, and Mr. Martin Trippe, go to prove that certain birds change their habits in a marked degree. In their behavior, too, certain birds, which are wild and suspicious in New England, are comparatively tame in the West. In their resting-places they show wide individual variation.

[1] "Proceedings of the Boston Society of Natural History," vol. xiv., p. 141.

[2] POPULAR SCIENCE MONTHLY, vol. vi., p. 481.

Prof. A. E. Verrill,[1] on the supposed eastern migration of the cliff-swallow, traces historically its first appearance in various places in the East, and is inclined to the opinion that as the country became settled by Europeans the birds left their native haunts for barns and houses, and increased in number to a greater extent than before on account of the protection invariably furnished by man.

Rev. Samuel Lockwood[2] records a curious case of the Baltimore oriole acquiring a taste for the honey-sacs of bees, tearing off the heads of those insects, and, having secured the honey-sacs, rejecting the rest of the body.

Prof. Wyman[3] observes a curious case in Florida of a colt and a number of pigs and cows thrusting their heads under water and feeding on the river-grass, in some cases remaining with their heads immersed for half a minute.

Hon. A. H. Morgan[4] observes the widest difference in the habits of the same species of beaver in the Lake Superior region and in the Missouri, constructing their dams and ways differently, and meeting the varied conditions, not by a blind instinct, but by a definite intelligence manifested for definite purposes.

All of these facts, simple in themselves, yet together go to prove that animals do vary in their habits, and with a persistent change in habits arises the minute and almost insensible pressure to swerve and modify the animal.

So much does the influence of season, with its accompanying peculiarities of food, temperature, humidity, and the like, affect certain animals developing coincidently with its different phases, that it is instructive to note that in certain species of insects two or three different forms occur. Thus Mr. Edwards[5] has in an elaborate way worked up the history of a polymorphic butterfly (*Ephiclides ajax*), showing that there are three forms heretofore regarded as distinct species, which are only varieties of one and the same species, but appearing at different times of the year, and consequently confronted by different influences as to temperature, moisture, food, and the like. These forms are known under the names of *Walshii*, *Telemonides*, and *Marcellus*, and both sexes are equally affected. The first form mentioned represents the early spring type, *Telemonides* the late spring type, and *Marcellus* the summer and autumn type (*see* also Mr. Scudder's paper[6]). If these influences affect species, we should expect to see the greatest variety of forms in a country possessing the widest diversity of conditions.

Some suggestive paths of investigation have been pointed out by

[1] "Proceedings of the Boston Society of Natural History," vol. ix., p. 276.

[2] *American Naturalist*, vol. vi., p. 721. [3] Ibid., vol. viii., p. 237.

[4] " "The American Beaver and his Works."

[5] "Butterflies of North America," part ix.

[6] *American Naturalist*, vol. viii., p. 257.

Prof. N. S. Shaler[1] on the connection between the development of the life and the physical conditions of the several continents, showing first that the greatest amount of shore-line in proportion to the internal areas indicates a greater diversity of surface within.

Another proposition he attempts to establish: that in proportion to the shortness of the shore-lines, or, in other words, to the want of variety in their surfaces, will be the diversity of animal life in the continent. He then proceeds from Darwin's standpoint, and follows out many curious and instructive lines of thought regarding increased amount of influences in diversified surfaces—a level plain having the same conditions throughout, but a mountainous region having for each one thousand feet of elevation a new condition of things, in the form of streams, winds, humidity, and the like. In areas of simple outline and unvarying surfaces we do, in fact, have a less diversity of forms.

Recognizing the mutation of continents through past geologic ages, we again see the accompanying physical changes in not only modifying forms, but in selecting them afterward by succeeding changes.

The widely-diversified nature of the facts bearing on the doctrine of natural selection baffles all attempts at a systematic classification of them. Of such a nature are many of the valuable communications of Prof. Wilder.

At the meeting of this Association[2] he has, among other matters, confirmed in a young lion the discovery of Prof. Flowers that, in the young dog and probably in other carnivora as well, the scapho-lunar bone has at the outset three centres of ossification, and that these really represent the *radiale intermedium* and *centrale* of the typical carpus. By study of a fœtal manatee, Prof. Wilder is able to determine its affinities, and to point out the probable retrograde metamorphosis of some ancient ungulate animal, and that the manatee is widely removed from the whales with which it has been associated.

Mr. William K. Brooks has published a very remarkable paper on certain free swimming tunicates, the *Salpa*, giving for the first time a clear and comprehensive history of certain obscure points, and has at the same time applied the principles of natural selection theoretically in showing the origin of salpa from sessile tunicates, and making clear the peculiar modification of parts which accompany these changes.

In the field of entomology some capital work has been done, both practical and theoretical.

Prof. Riley's demonstration of the yucca-moth is unique in its way. Dr. Engelmann has discovered that the yucca depends upon insects for fertilization; and Prof. Riley, by patient study, not only

[1] "Proceedings of the American Academy," vol. viii., p. 349.

[2] "Proceedings of the American Academy of Arts and Sciences," vol. xxii., p. 301.

discovered the moth which fertilizes the flower, but finds an anomalous change in the maxillary palpi of the insect, by means of which the moth collects bundles of pollen, which it inserts into the stigmatic tube, and during this peculiar act deposits her eggs in the young fruit. Prof. Riley has reasons to believe that this is the only insect engaged in the fertilization of this plant. A mutual dependence is here met with of extreme interest. The yucca unfertilized forms no fruit, and the larva of the moth consequently perishes.

Prof. Augustus R. Grote, in an examination of butterflies, finds successive gradation in their structures, and shows that as these organs "become less serviceable to the insect they become more rigid and in position more elevated above the head in the butterfly, while in the moth they are more whip-like and directed forward." While protesting against the separations which have been made in the order based upon the antennæ, he directs attention "to the real differences in antennal structure between the butterflies and moths, while showing that the antennæ are modified by desuetude in the higher and former group." Prof. Grote,[1] in dealing with a family of moths, the *Noctuidæ*, calls attention to the unequal value of *Acronycta*, and is forced to admit that these differences become clear through the theory of evolution. He says: "Where in *Acronycta* there is a general prevailing uniformity in the appearance in a single group of species and generally broad distinctions between the larval forms, it is a not unreasonable conclusion that these larval differences are gradually evolved by a natural protective law, which intensifies their characters in the direction in which they are serviceable to the continuance of the species."

Those who have believed in types as fixed laws, rigidly impressed at the outset of life, are those also who have recognized in the cells of a honey-bee, as well as in the arrangement of leaves about the axis of a plant, a perfect mathematical adjustment of parts, which were stamped at the beginning, and have so continued to exist without deviation. For nearly two hundred years it has been believed that the instinct of a bee guided it to shape a cell which of all other forms should use the least amount of material. A theory having been established as to the constant shape of a bee's cell, namely, that it was an hexagonal prism with trihedral bases, each face of the base being a rhomb with certain definite angles, a mathematician was given the problem to construct similar cells, and to determine the best possible form with the use of the least amount of material. The coincidence between theory and observation and experiment was so remarkable as to settle apparently for all time the question as to the perfectly-implanted instinct of the bee with its unconscious power of accurate work. Prof. Jeffries Wyman,[2] to whose memoir I am indebted

[1] "Proceedings of the Buffalo Society of Natural Science," vol. i., p. 130.

[2] "Proceedings of the American Academy," vol. vii., p. 68.

for the above facts, has by an ingenious study of the cells of bees shown, first, that, a cell of this perfection is rarely if ever attained. Furthermore, that, while the honey-cells "are built unequivocally in accordance with the hexagonal type, they exhibit a range of variation which almost defies description;" that the worker-bees, from incorrect alignment and other causes, build cells, the measurement of which shows the widest limit of variation; that the drone-cells are liable to substantially the same variations, while the transition-cells, namely, those in which drones and worker-cells are combined in the same piece of comb, are extremely irregular. As the drone-cells are one-fifth larger than worker-cells, "a transition cannot be made without some disturbance in the regularity of the structure." And Prof. Wyman states distinctly that the bees do not have any systematic method of making the change, adding that "the cell of the bee has not that strict conformity to geometrical accuracy claimed for it," and the assertion, like that of Lord Brougham, that there is in the cell of the bee "perfect agreement between theory and observation, in view of the analogies of Nature, is far more likely to be wrong than right, and his assertion in the case before us is certainly wrong." Prof. Wyman closes his essay by saying that "much error would have been avoided if those who have discussed the structure of the bee's cell had adopted the plan followed by Mr. Darwin, and studied the habits of the cell-making insects comparatively, beginning with the cells of the humble-bee, following with those of the wasps and hornets, then with those of the Mexican bees, and finally with those of the common hive-bee; in this way they would have found that, while there is a constant approach to the perfect form, they would at the same time have been prepared for the fact that even in the cell of the hive-bee perfection is not reached. The isolated study of anything in Nature is a fruitful source of error."

The remarkable ingenuity, so characteristic of Prof. Wyman's experiments, is fully shown in this memoir. He made plaster-casts of the comb, and then sawed transverse sections, and by slightly heating the plaster the wax was melted and absorbed, leaving the delicate interspaces representing the partitions. From these sections electrotypes were taken, and thus the veritable figures were used to illustrate the absolute structure of the comb. The results of these brilliant researches were published in the "Proceedings of the American Academy of Sciences."

[*To be continued.*]

THE EARLY HISTORY OF FIRE.[1]

By Professor N. JOLY,
OF THE FACULTY OF SCIENCES, TOULOUSE.

FIRE, the common source of heat, of light, and of life, and the active principle of a multitude of industries, and of metallurgical industry in particular, is unquestionably one of the greatest conquests achieved by man over Nature.

The discovery of fire was more than a benefit; it was, in fact, a giant stride on the road to civilization. With fire arose sociability, the family, the sacred joys of the domestic hearth, all industries, all arts, together with the wonders they have produced, and still produce from day to day. Hence we can readily understand how it is that fire has ever been and still is, among many nations, the object of a special worship (priests of Baal, Ghebers, Hindoo Brahmans, Roman vestals, priestesses of the sun in Peru, etc.); and that it has often figured in the religious or funereal rites of nations most remote from one another, both in time and space, as the Chaldees, Hebrews, Greeks, Romans, Peruvians, Mexicans, etc. But how and when was this great discovery made, in the absence of which we can hardly conceive of the possibility of human arts or even of human existence? Did man, as we are told in the myths of India and Greece, steal fire from heaven; or did he, as other legends affirm, take advantage of spontaneous forest-fires, arising from the violent rubbing together of dry branches under the action of the wind; or, finally, was man so ingenious, even from the beginning, as to devise one of those simple and practical contrivances by means of which certain savage and half-civilized tribes in our own time obtain the fire they need for their daily uses?

However far back we may trace man's history, we find him always in possession of fire. The story of Prometheus getting fire from Olympus is nothing but the Vedic myth which tells of the god Agni, or heavenly fire (Latin, *ignis*), as squatting in a hiding-place whence he is compelled by Matarichvan to come forth in order to be communicated to Manu, the first man, or to Bhrigu (*the shining one*), the father of the sacerdotal family of the same name.

The very name of Prometheus is of purely Vedic origin, and calls to mind the process employed by the ancient Brahmans in getting the sacred fire. For this they used a spindle called *matha* or *pramatha*, the prefix *pra* adding the idea of *taking by force* to the signification of the root *matha;* this latter is from the verb *mathnâmi*, or *manthâmi*—"to bring out by friction." Prometheus, therefore, is the one who discovered fire, brings it forth from is hiding-place, steals it and gives it

[1] Translated from the French by J. Fitzgerald, A. M.

to mankind. From Pramanthâ, or Prâmâthyus—"he who hollows out by rubbing," "he who steals fire"—the transition is easy and natural, and there is only one step from the Indian Prâmâthyus to the Prometheus of the Greeks, who stole the heavenly fire to light the spark of life, the soul, in the clay-formed man.

The spindle or *pramantha* had wound round it a cord of hemp mixed with cow-hair, and with this cord the priest of Brahma gave it an alternating rotary motion from right to left and from left to right. In rotating the spindle, one end of it rested in a depression made at the intersection-point of two crossed pieces of wood, the ends of which were bent to a right angle, and firmly secured with four bronze nails, thus preventing them from moving. The entire apparatus was called *swastika*.[1] The father of the sacred fire was named Twastri, i. e., the divine carpenter who made the *swastika* and the *pramantha*, the mutual rubbing of which together produced the divine babe Agni. Its mother was named Maya. Agni took the name of Akta (i. e., *anointed*, christos) after the priest had poured on its head the *soma*, and on its body the purified butter of the sacrifice.

In his interesting work on the "Origin of Fire," Adalbert Kuhn gives to the 卐 and to this other like sign, 卐, the name of *arani*, and both of them he regards as the religious symbols, *par excellence*, of our old Aryan ancestors—the symbols of sexual reproduction.

This fire-myth occurs also in the Zendavesta, or sacred book of the Persians, and in the Vedic hymns of the Hindoos, under a twofold form, both material and metaphysical. But the authors of these hymns bear witness that this same myth was, long before their time, symbolized in a great national religion, the founder of which, Rhibu, is no other than Orpheus. This tradition, common to Greeks, Hindoos, and Persians, carries us back to those ancient times when the as yet undiscovered branches of this stock wandered upon the banks of the Oxus.

In his "Researches into the Early History of Mankind," Tylor gives interesting details about the discovery of fire, and the various modes of obtaining it in every age. The primitive method of all would seem, according to him, to have consisted in rubbing together two pieces of dry wood, but this process was perfected in the course of time. Thus, friction is produced by means of a stick which is made

[1] It is well worthy of note that the *swastika*, 卐, of India occurs very frequently in two forms, viz., 卐 and , on the earthen-ware disks found in such great numbers by Dr. Schliemann among the ruins of ancient Ilium. From this it would seem to follow that the Trojans were of Aryan origin. As for the analogies, or even direct resemblances, between certain ceremonies to the worship of Agni and certain rites of the Catholic worship, they, too, may be explained, at least to some extent, by community of origin: Agni, as *Akta*, would be Christ; Maya, the Virgin Mary; Twastri, Saint Joseph.

to slide rapidly to and fro upon a piece of dry, soft wood laid upon the ground (in Tahiti, the Sandwich Islands, New Zealand, Timor, etc.). This process Tylor denominates the stick-and-groove (Fig. 1), but the fire-drill (Figs. 2 and 4) is more generally used. In its simplest form, the fire-drill consists of a stick, one extremity of which is inserted in

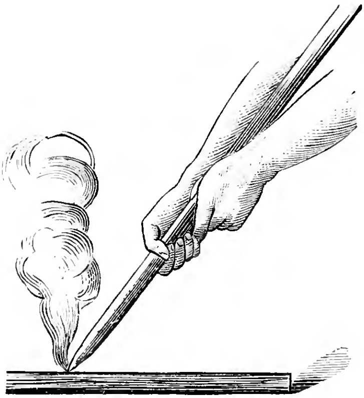


FIG. 1.—THE STICK-AND-GROOVE. (Tylor.)

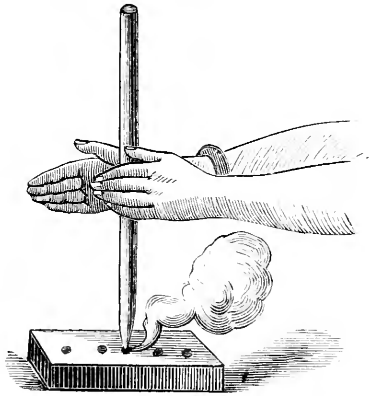


FIG. 2.—THE FIRE-DRILL. (Tylor.)

a hole bored in a piece of dry wood, while the stick itself is twirled between the hands and pressed downward (*see* Fig. 2).

This instrument occurs not only in Australia, Sumatra, the Caroline Islands, and Kamtchatka, but also in China, South Africa, and North and South America. It was employed by the ancient Mexicans, and is still in use among the Yenadis of Southern India, and the Veddas of Ceylon (Fig. 3).

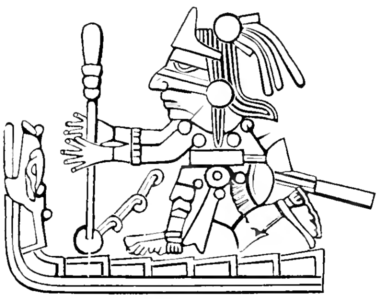


FIG. 3.—ANCIENT MEXICAN FIRE-DRILL. (Tylor.)

It is still further modified by causing the stick to whirl by means of a thong wound round it, the ends of which are pulled in opposite directions alternately. This is the instrument described in the Vedas, and it is still employed by the Brahmans of our own day for lighting the sacred fire. For, as Tylor well observes, we very often see fire obtained for use in religious rites by the ancient processes,

rather than by the readier means discovered in later times. Thus, when the vestals permitted the sacred fire to go out, it was rekindled by means of the sun's rays, concentrated by a lens. A similar method was employed by the ancient priests of Peru in kindling the sacrificial fire.

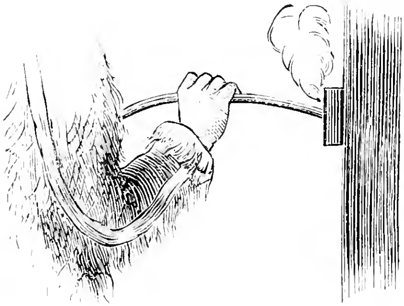


Fig. 4.—Fire-Drill of the Gauchos. (Tylor.)

An instrument resembling that employed by the Brahmans of India is to this day in use among the Esquimaux and the Aleuts (Fig. 6). It consists of a rod, one end of which fits into a mouth-piece, and the other into a hole in a piece of dry wood. The rod is twirled by means of a thong wound twice around it, and pulled to the right and left alternately by the hands.

Slight modifications occur in the form of the fire-drill, and various instruments have been devised to serve the same purpose. For instance, there are the bow-drill and the pump-drill, which latter is used both for obtaining fire and for boring holes in wood, stone, and metal (Figs. 5 and 7).

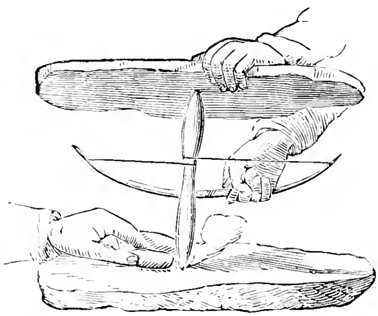


Fig. 5.—Bow-Drill, used by the Sioux. (Tylor.)

Of other means of procuring fire we will simply mention, in passing, the striking together of flints, or flint and steel, or iron pyrites; striking together two pieces of bamboo (this method peculiar to China); compressing air in a tube of ivory or of wood (a process adopted by the Malays, etc.).

The dried parenchyma of the *Boletus igniarius*, frayed cedar-bark, dry leaves, carbonized vegetal fibres, and the like, are the combustible materials commonly employed to receive the spark produced by friction or by concussion.

Is there or has there ever been a people absolutely ignorant of the means of producing fire? Many authors answer this question affirmatively. Thus we are told that the natives of Tasmania, though acquainted with fire and making use of it, nevertheless are ignorant of the means of producing it. Hence it is the special duty of their women to carry fire-brands that burn day and night, and by the light of which the tribe make their way through the woods. If the torches or brands go out, it may be necessary to make a long journey in order to have them lighted again from the fire kept up by another tribe. Nearly every family, too, carries about a cone of banksia, which burns slowly like amadou.

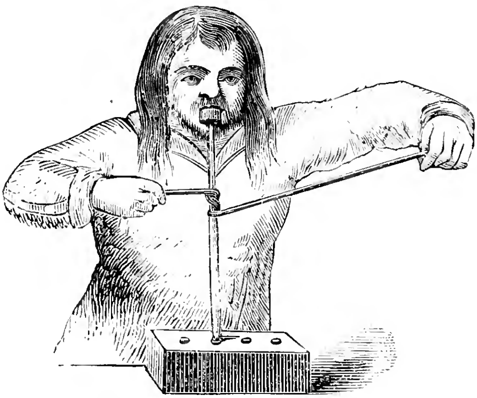


Fig. 6.—Esquimau Thong-Drill. (Tylor.)

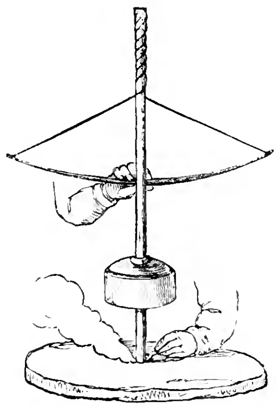


Fig. 7.—Pump-Drill. (Tylor.)

That the Australians are not so ignorant of the uses of fire as they are said to be, is shown by a legend current among them about the origin of fire. This legend we copy from Wilson, who, in his work, "Prehistoric Man," devotes a highly-interesting chapter to the question we are considering: "A long, long time ago, a little bandicoot[1] was the sole owner of a fire-brand, which he cherished with the greatest jealousy. So selfish was he in the use of his prize that he obstinately refused to share it with the other animals. So they held a general council, where it was decided that the fire must be obtained from the bandicoot either by force or strategy. The hawk and the pigeon were deputed to carry out this resolution; and, after trying to induce the fire-owner to share its blessings with his neighbors, the pigeon, seizing, as he thought, an unguarded moment, made a dash to obtain the prize. The bandicoot saw that affairs had come to a crisis,

[1] A small, sharp-nosed animal, not unlike the Guinea-pig.

and, in desperation, threw the fire toward the river, there to quench it forever. But, fortunately for the black man, the sharp-eyed hawk was hovering near, and, seeing the fire fall into the water, with a stroke of his wing he knocked the brand far over the stream into the long, dry grass of the opposite bank, and the flames spread over the face of the country. The black man then felt the fire, and said it was good."[1]

Did prehistoric man possess fire? If we are to believe the Abbé Bourgeois, man was in possession of fire since Miocene times. This assertion rests upon the discovery in the sands of the Orleanais of a fragment of artificial *paste*[2] mixed with charcoal, and lying in the midst of mastodon and dinotherium bones. It also rests, but not so firmly, upon the discovery by the same *savant* of cracked flints in the neighborhood of Thenay, not far from the banks of the lake of Beauce. These flints appear to bear plain traces of the action of fire; but may not these be due to lightning? If not, where are the ashes, where the charcoal which naturally would accompany the flints if they had been really brought under the action of fire? Then, where is the fire-place? Hence, the Abbé Bourgeois's deduction is not an impossible one, though in my opinion it is by no means demonstrated.

But, though the discovery of fire in Miocene times may be questioned, it cannot be denied that in the earliest Quaternary times this element was known to man. Several fireplaces, ashes, charcoal, bones, either entire or partly calcined, fragments of coarse pottery blackened by smoke, and similar objects, have been found in caverns belonging to the epoch of the Cave Bear, and of the Reindeer and the Polished Stone age. These things prove that the men who inhabited the caves commonly enough cooked their food, thus making it more readily digestible.

With the aid of fire, prehistoric man cremated his dead, hollowed out his pirogue, and saved from too rapid destruction the lower extremity of the piles on which he built his lake-dwellings. And not only did the troglodyte and the lacustrian know how to cook their food and warm their habitations, but they also were acquainted with various methods of lighting them during the darkness of night. There have been found in the Lake of Geneva carbonized sticks of resinous wood, which, in all probability, once were employed for this latter purpose. Just as the Esquimaux now light their snow huts by means of lamps fed with the oil of the porpoise or the whale, so did the Danes of the kitchen-middens use, for illuminating purposes, a wick made of moss, one end of which was introduced into the stomach of a great penguin (*Alca impennis*) filled with fat.

The use of flint, quartz, and iron pyrites, in the Lacustrian period, for procuring fire by striking these substances against one another, is

[1] Vol. i., p. 139.

[2] Paste, the mineral substance in which other minerals are imbedded.—WEBSTER.

proved by the discovery, in the lakes of Switzerland (at Meilen, Moosseedorf, Wangen, and Robenhausen), of bits of tinder prepared from the *Boletus igniarius.* And, if we accept the views of Messrs. Ed. Lartet and Christy with regard to certain blocks of granite, hollowed out in the centre, which have been found in the caves of Périgord, these blocks would appear to have been intended for the purpose of procuring fire by rapidly rotating a wooden rod in the central cavity, as is done by the priests of Brahma.

And, indeed, how could it happen that fire should have been unknown even in the earliest periods of Quaternary time, considering the chances of fire being struck from these flints, whether in the workshop or in battle, and of the sparks falling upon combustible materials—for instance, dry leaves? This explanation we hold to be simpler and more natural than the other, which refers the discovery of fire to the spontaneous conflagrations of forests, or to the friction of dry branches of trees.

Fire, we repeat with profound conviction, must have been very early known to man, for we cannot conceive of his living without it. And hence, "who can picture the joy, the gladness, the radiant ecstasy of that one of our unknown forefathers who first triumphantly exhibited to his astonished tribesmen the smoking brand from which he had succeeded in causing flame to burst forth?" [1]

Thus we have seen that fire gave rise to nearly all the arts, or at least promoted their development. Metallurgy, architecture, ceramic arts, agriculture, navigation, commerce, industry, all are quickened by its vivifying flame. It has played, and still does play, an important part in the religious ceremonies and the funereal rites of nations, both savage and civilized. But then, in turn, as though by a law of Fate, evil accompanies the good: fire destroys with greater rapidity than it produces by forging those formidable engines, those implements of death, by which in the twinkling of an eye the flower of nations is cut down on the battle-field.—*Revue Scientifique.*

PHYSICAL SCIENCE IN ENGLISH SCHOOLS.

At a meeting of the British Association five years ago, the subject of science-teaching in our higher schools excited unusual interest. Not only were papers read and followed by enthusiastic discussion, but a committee was privately formed, including more than twenty leaders of the Association, all of whom undertook to combine in pressing the claims of science on our head-masters, and in offering counsel as to systems and methods, apparatus, and expenditure.

[1] Albert Réville, *Revue des Deux Mondes*, tome xl.

Technical difficulties prevented the formal nomination of the committee in that year; and before the next meeting came round the Science Commission was in full work, and the ground was covered. Five years have passed; the commission has reported; and the British Association, if it deals at all with the problem that lies at the root of our scientific progress, will have to face the fact that only ten endowed schools in England give as much as four hours a week to the study of science; in other words, that, in spite of ten years of talk, the *éclat* of a Royal Commission, a complete consensus of scientific authority, and the loud demands of less educated but not less keen-sighted public opinion, the organization and practical working of science in our higher schools has scarcely advanced a step since the Schools Inquiry Commission reported in 1868.

Are the causes of this strange paralysis discoverable, and are they capable of present remedy? We believe that they are notorious, and that it is in the power of the British Association at the present moment to overrule them. It is therefore in the hope of rekindling a productive enthusiasm at a critical moment in the history of our science-teaching that we appeal with all the earnestness of which we are capable to the leaders of the great parliament, whose session will have opened before this goes to press.

The first obstacle to be understood and reckoned with is the amazing confusion in the minds of unscientific leaders of opinion as to the very nature of education. An ex-Lord Chancellor gives away prizes to a school, declares in stately terms that Greek and Latin must always form the backbone of high intellectual training, and that the sciences can only be tolerated as a sort of ornament or capital to this great central vertebral column. On the following day an ex-Chancellor of the Exchequer gives away prizes at another school, assures the boys that modern scientific teaching is their being's end and aim, and envies them by comparison with himself, who at Winchester and Oxford basked only in the "clarum *antiquæ* lucis jubar."[1] In all such public utterances chaos reigns supreme. Men take side with one or other branch of mental discipline, unconscious of the Nemesis which waits on the divorce of literature from science, or of science from literature, forgetful of the fundamental truths that all minds require general training up to a certain point, and that the period at which special education should supervene is the problem which awaits solution.

The hostility of the clergy ranks high among the difficulties we have to recognize. To the great public schools this is matter of indifference; but the vigorous head-master of a young and rising county school, who attempts, being himself a clergyman, to make real science compulsory in his school, is rattened by the vulgar heresy-hunters, who swarm in every diocese. The hint and shrug in society, the whisper at clerical conferences, the warning to parents attracted

[1] The bright radiance of *ancient* light.

by the school against "atheistic tendencies," keep down his numbers and wear out his energies, till his enterprise becomes a warning instead of an example to his admirers at other schools. In a neighborhood of rural squires and clergy, untempered by a large town's neighborhood, and unchecked by any man of education and intelligence holding sovereignty by virtue of superior rank and wealth, a school which treads doggedly in the ancient paths, and is flavored with gentle "High-Church tendencies," will certainly succeed even in second-rate hands, while a school which under superior chieftainship asserts the claims of science, and whose theology is therefore suspect, will as certainly long struggle for existence, if it does not finally succumb.

The head-masters, with no inveterate intention, but by the force of circumstances, are potent allies upon the side of nescience. Their position is peculiar. Enlightened, able, high-minded, and most laborious, to speak of them with disrespect would be to forfeit claim to a hearing. But of their whole number not more than two or three know anything at all of science; they have gained honors and supremacy by proficiency in other subjects; to teach well these subjects which they know, forms their happiness and satisfies their sense of duty; and they feel natural dismay at the proposal to force upon them new and untried work which they have not knowledge to supervise, and which must displace whole departments of classical study. Bifurcation they do not mind, for they hope that the dunces will be drafted into the modern school, and the clever boys retained upon the classical side; but the momentous recommendation of the Royal Commission that six hours a week of science-teaching should be given to every boy in every school has taken away their breath; it was only once alluded to at the last head-masters' meeting, and then with something between a protest and a sneer. They are too clear-sighted not to see that the demand for science-teaching is real, and too liberal not readily to accede to it, if some central authority, which they respect, at once puts pressure on them, and tenders such assistance and advice as they can trust. But, until these two things are done, they will pursue a policy of inaction.

Nor is there any hope that this reluctance of head-masters will be stimulated by exuberant energy on the part of governing bodies. The instances in which these pet creations of the Endowed Schools Commission have appeared before the public hitherto make it evident that absolute inactivity is the service they are best calculated to render to the cause of education; but their probable devotion to science may be guessed from an incident reported in our columns some months ago, where a body of trustees, composed of country gentlemen of local mark, having to arrange a competitive examination under a scheme of the Charity Commission, adopted the machinery of the University Leaving Examination, but inserted a distinct proviso that no scientific subject recognized by the university regula-

tions should under any circumstances be taken up by the candidates, either as an alternative or a positive branch of work.

Will the universities help or impede the spread of school science-teaching? The universities adhere at present to their fatal principle that only one-sided knowledge shall find favor within their walls. A boy who knows nothing but classics, nothing but mathematics, nothing but science, may easily win a scholarship; a boy who knows all three must seek distinction elsewhere; and this rule shapes inevitably the teaching of the schools. The science scholarships at Oxford, of which we hear so much, fall mainly to three distinguished schools: two so large and wealthy that they can overpower most competitors by their expenditure on staff and apparatus; the third planted in Oxford, with access to the university museum and laboratory, and with a pick of teachers from the men of whom examiners are made; and these schools insure success in science by abandoning other subjects almost or altogether in the case of the candidates they send up. No school which should carry out the recommendations of the commissioners by giving six hours a week to science, and the rest of its time to literature and mathematics; no school which should realize its function as bound to develop young minds by strengthening in fair proportion all their faculties of imagination, reason, memory, and observation—could offer boys for any sort of scholarship under the present university system with the faintest chance of success.

What these institutions are powerless to avert or helpless to bring about is, we repeat, within the scope of the British Association to effect. All institutions, political or educational, will bow to a strongly-formed committee of scientific men, formally commissioned by the Association and speaking with authority, delegated as well as personal, on scientific subjects. Let such a committee be revived as died on paper in 1871, including the acknowledged leaders of pure science, and weighted with the names of such educationalists as have shown themselves zealous for science-teaching. Let their functions be—1. To communicate with the head-masters and governing bodies, calling attention to the recommendations of the Duke of Devonshire's commission, asking how far and how soon each school is prepared to carry these out, and tendering advice, should it be desired, on any details as to selection and sequence of subjects, teachers, text-books, outlay. 2. Let them appeal to the universities, to which many of them belong, as to the bearing of science scholarships and fellowships upon school-teaching, and the extent to which such influence may be modified or ameliorated in that rearrangement of college funds which next session will probably be commenced. 3. Let them be instructed to watch the action of Government in any proposal made either in pursuance of Lord Salisbury's bill, or as giving effect to the Duke of Devonshire's commission, and let them be known to hold a brief for school science in reference to all such legislation. A

single meeting of such a committee before the Association separates would settle a basis of action and compress itself into a working sub-committee. The time for papers and discussions is past; they have done their work. What the schools and the head-masters want is authoritative guidance—the guidance not only of a blue-book, but of a living leadership, central, commanding, and accessible, to which they may look with confidence, and bow without loss of prestige.

The precision of its *dicta* will clear up public confusion; its ability, conscientiousness, and popularity, will overawe the clergy; schools and universities will listen respectfully to suggestions echoed by their own best men; and the three great departments of intellectual culture, equal in credit, appliances, and teaching power, will bring out all the faculties and elicit the special aptitudes of every English boy.

"Hinc omne principium, huc refer exitum."[1]

—*Nature.*

NATURE OF THE INVERTEBRATE BRAIN.

By Professor H. CHARLTON BASTIAN.

II.

IT now remains for us to consider the disposition of the nervous system in some of the principal types of the sub-kingdom *Mollusca.*

These are animals wholly different in kind from those we have just been considering, mostly aquatic, and all of them devoid of hollow, articulated, locomotor appendages. Their organs of vegetative life attain a disproportionate development. On the other hand, what are termed the "organs of relation" present a wide range of variation, as may be imagined from the fact that while some of the simplest representatives of the *Mollusca* consist of mere motionless sacs or bags, containing organs of digestion, respiration, circulation, and generation, its more complex forms are active predatory creatures, endowed with remarkable and varied powers of locomotion, and with sense-organs as keen and as highly developed as those of insects. The lower type is represented by the motionless ascidian, and the higher by the active and highly-endowed cuttle-fish.

Omitting any reference to the *Polyzoa*, we may turn our attention first of all to the *Tunicata*, of which the solitary ascidians may be taken as the type. They are marine animals, possessing no powers of locomotion, and having no head. The current of sea-water, serving for respiratory purposes, and, at the same time, containing food-particles, enters a large branchial chamber, through an open, funnel-like projection of the investing tunic of the animal, the orifice of which

[1] With this begin, to this refer the end.

is guarded by sensitive tentacula and a sphincter muscle. The mouth is situated at the bottom of this branchial sac, down the side of which minute particles of food are swept by ciliary action, so as to be brought within the simple commencement of the œsophagus. The effete sea-water passes through the walls of this branchial cavity into a general body-chamber, in which the viscera are contained. This cavity is bounded externally by a muscular expansion, lining the outer cellulose tunic. By the periodical contraction of this muscular sac, the water which enters it, together with food-residues and ova, is expelled through another funnel-like opening, adjacent to and very similar to that by which it gains entry to the branchial chamber.

Although these ascidians have a definite alimentary canal, a circulatory system, and respiratory organs, together with a distinct genital apparatus, their life of relation with the external world is of the simplest description. They are stationary creatures, and have no prehensile organs, food being brought to the commencement of their alimentary canal by ciliary action.

In correspondence with such a simple mode of life, we might expect to find a very rudimentary nervous system, and this expectation is fully realized. The *Tunicata* possess a single small nervous ganglion lying between the bases of the two funnels through which water is taken in and discharged. This ganglion receives branches from the tentacula guarding the orifice of the oral funnel, and possibly from the branchial chamber, while it gives off outgoing filaments to the various parts of the muscular sac, and perhaps to the alimentary canal, and some of the other internal organs. In some of the solitary *Tunicata* a rudimentary visual function is presumed to exist. At all events, pigment-spots are situated on, or in very close relation with, the solitary ganglion. This single body seems to serve for the performance, in a rudimentary manner, of the various functions discharged by at least two pairs of ganglia in a large number of higher *Mollusca*, viz., those known as the cerebral and the parieto-splanchnic or branchial.

The brachiopods are among the oldest and most wide-spread of the forms of life in the fossil state, and the geographical distribution of their living representatives at the present day is also very wide. Like the *Tunicata*, they are headless organisms, and lead a sedentary existence, attached either by a pedicle or by one division of their bivalve shells. The mouth is unprovided with any appendages for grasping food—nutritive particles being brought to it by means of ciliary currents. Numerous muscles exist which connect the valves of the shell to one another, and with the inclosed animal. And, though the visceral organization of the brachiopods is somewhat complex, no definite sense-organs have yet been detected in any of them. In the nervous system of these sedentary animals, there is, therefore, nothing answering to a brain as it is ordinarily constituted,

though ganglia exist around the œsophagus which must receive afferent impressions of some kind, and from which branches proceed to the various muscles and viscera of the body.

Such low sensory endowments as are presented by the *Brachiopoda* would be wholly incompatible with that degree of visceral complexity of organization which they possess, had it not been for the fact that they lead such a passive existence in respect to quest of food. They do not go in search of it at all—they remain securely anchored while food is brought to the entrance of their alimentary canal by means of cilia. The absence of sense-organs and of a brain is, indeed, only compatible with a *quasi*-vegetative existence such as this.

The lamellibranchs, or ordinary headless bivalve *Mollusca*, also include some representatives—such as the oyster and its allies—which lead a sedentary life after the fashion of the *Mollusca* already mentioned. The valves of the shell in these lamellibranchs are lateral, instead of being dorsal and ventral as among the branchiopods. The shell is, however, closed by a single adductor muscle, and it is opened, when this relaxes, by means of an elastic hinge.

The mouth of the oyster is surrounded by four labial appendages, whose functions are not very definitely known. It presents no other appendages of any kind in the neighborhood of the mouth, and, as in the two types of *Mollusca* already described, the food which it swallows is brought to the entrance of its œsophagus by means of ciliary currents. This well-known animal has a large and important nervous ganglion (Fig. 8, *b*) situated posteriorly, and close to the great ad ductor muscle. It gives off branches to this muscle, to each half of the mantle, to the gills (*c*, *c*), and it sends forward two long parallel branches (*d*, *d*), which serve to connect it with a much smaller anterior ganglion (*a*, *a*) situated on each side of the mouth. These anterior or labial ganglia are joined by a commissure arching over the mouth, and also by a more slender thread beneath the mouth, from which filaments (*e*) are given off to the stomach. These latter filaments may be considered to have a function similar to that of the stomatogastric nerves in insects. The anterior ganglia receive nerves (*f*) from the labial processes, probably for the most part afferent in function. At all events, these processes have no distinct muscular structure.

Other lamellibranchs possess a remarkable muscular appendage known as the foot, which is in relation with an additional single or double nervous ganglion, and is used in various ways as an organ of locomotion. The animals possessing this organ are also provided with a second adductor muscle for closing their shells. Speaking of the various uses of the foot among bivalves, Prof. Owen says: "To some which rise to the surface of the water it acts, by its expansion, as a float; to others it serves by its bent form as an instrument to drag them along the sands; to a third family it is a burrowing organ; to many it aids in the execution of short leaps."

These bivalves possessing a foot present three pairs of ganglia instead of two—the anterior or oval, the posterior or branchial, and the inferior or pedal. It occasionally happens, however, that the ganglia of the posterior or of the inferior pair become approximated or even fused into one. The fusion of the posterior pair takes place, as in the oyster, when the branchiæ from which they receive nerves come close together posteriorly. On the other hand, in those mollusks in which the branchiæ are farther apart, the two ganglia remain separate, and are connected only by a short commissure, as in the mussel (Fig. 9, *b*).

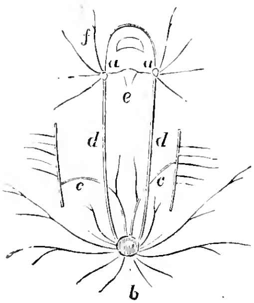


FIG. 8.—NERVOUS SYSTEM OF THE OYSTER.

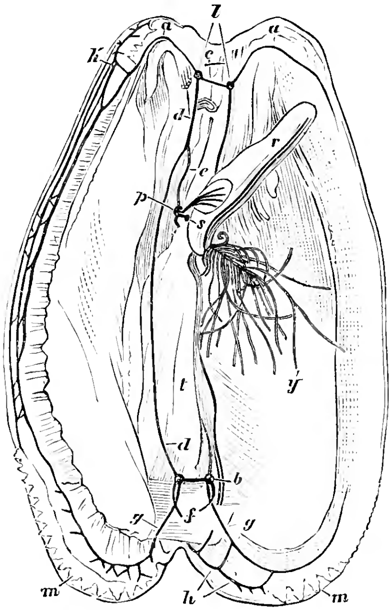


FIG. 9.—NERVOUS SYSTEM OF THE COMMON MUSSEL.

The separate existence or fusion of the inferior or pedal ganglia depends upon the size and shape of the foot. The nerves in relation with these ganglia are distributed almost wholly to this organ and its retractor muscles. Where the foot is broad the ganglia remain separate, and are merely connected by a commissure. But where the foot is small and narrow, as in the mussel, the two ganglia become fused into one (Fig. 9, *p*).

Some of the special senses are unquestionably represented among these headless *Mollusca*, though the distribution of the different organs is very peculiar. Thus in *Pecten*, *Pinna*, *Spondulus*, the oyster, and many others, very distinct and often pedunculated ocelli are distributed over both margins of the pallium or mantle. These vary in number from forty to two hundred or more, and are in connection with distinct branches of the circumpallial nerves. In the razor-fish,

the cockle, Venus, and other bivalves possessing those prolongations of the mantle known as siphon-tubes, the eyes are situated either at the base or on the tips of the numerous small tentacles distributed around the orifices of these tubes, which in those of them living in the sand are often the only parts appearing above the surface. The margins of the mantle are also garnished by a number of short though apparently very sensitive tentacles, in which the creature's most specialized sense of touch seems to reside. Some of these tactile appendages, as well as some of the ocelli, send their nerves to the posterior or parieto-splanchnic ganglia, while those situated on the anterior borders of the mantle communicate with the anterior or oral ganglia. The latter ganglia also receive filaments from the so-called labial appendages, whose function is uncertain, though it has been suggested that they may be organs of taste or smell. Lastly, in close relation with the pedal ganglia or ganglion, there are two minute saccules (Fig. 9, *s*), to which an auditory function is usually ascribed.

Thus we find among these headless mollusks a distribution of specially impressible parts or sensory organs, such as cannot be paralleled among any other animals. The sense of touch and the sense of sight seem to be more especially in relation with the great posterior ganglia. These sensory functions are, however, to a minor extent shared by the oral ganglia, which are also in relation with parts that may possibly be organs of taste or smell. On the other hand, auditory impressions are invariably brought into relation with the inferior or pedal ganglia. In these headless mollusks, therefore, the functions pertaining to the brain in other animals are distributed in a very remarkable manner, and the anterior ganglia cannot in them be properly regarded as representing such an organ.

The viscera in these lamellibranchs are also in relation with the three pairs of ganglia, and not exclusively with any one of them. Filaments to the intestinal canal and the liver are usually given off from the commissures between the anterior and the posterior ganglia; the genital organs are in connection with filaments coming from the commissures between the anterior and the inferior or pedal ganglia; while the branchiæ are in relation with the ganglia at the posterior part of the body.[1]

There is another interesting class of mollusks—the *Pteropoda*—which, in respect of powers of locomotion and the possession of a distinct head, may, if for no other reasons, be said to lead us on from the comparatively sluggish bivalve *Mollusca* to the gasteropods and the cephalopods, all of which are distinguished by definite and wide-reaching powers of locomotion, and by the possession of a distinct head carrying sense-organs, and a more or less developed brain.

[1] In speaking of the nervous system of the lamellibranchs, I have not alluded to certain small accessory ganglia which exist in some of them in relation with peculiar specially developed contractile structures.

The possession, by many members of this class, of two fin-like muscular expansions attached to the side of the head induced Cuvier to give them the name *Pteropoda*. Prof. Owen says: "All the species of *Pteropoda* are of small size; they float in the open sea, often at great distances from any shore, and serve, with the *Acalephæ*, to people the remote tracts of the ocean. In the latitudes suitable to their well-being, the little *Pteropoda* swarm in incredible numbers, so as to discolor the surface of the sea for leagues; and the *Clio* and the *Limacina* constitute, in the northern seas, the principal article of food of the great whales."

Some of the least highly-organized members of this class, such as the *Hyalaceæ*, are provided with a bivalve shell, and cannot be said to possess a head. They have a simple commencement of the alimentary canal at the anterior extremity of the body; but since this anterior extremity has no tactile appendages and no eyes, and inasmuch as it also contains no cerebral ganglia, it can have no claim to be considered as a head. Their chief nervous centre consists of a flat, somewhat quadrate, sub-œsophageal ganglion, to the anterior angles of which is attached a nervous commissure which extends upward so as to encircle the gullet, though there are no ganglia either on or at the sides of this tube in the usual situation occupied by cerebral ganglia.

In other pteropods devoid of a shell, we meet with a higher organization. Thus in *Clio* there is a distinct head bearing sensory appendages in the form of two tentacula and two eyes, and containing in its interior a brain. This brain is represented by two connected super-œsophageal ganglia, which are in relation, by means of nerves, with the cephalic sensory organs, and in connection with the sub-œsophageal commissure are the two pedal and two branchial ganglia. The two pairs of ganglia exist separately in *Clio* and its allies, though they are combined into one quadrate mass in *Hyalea*. In this latter there are two acoustic vesicles in contact with the anterior part of the great ganglion, while in *Clio* similar vesicles are in connection with the anterior pair of sub-œsophageal ganglia—that is, with the pair which corresponds with the pedal ganglia of the common bivalve mollusks.

Gasteropods constitute a class of organisms which, in point of numbers, can only be compared with the still more numerously represented class of insects. Their name is derived from the fact that these animals crawl by means of a large muscular expansion stretched out beneath the viscera. The locomotion of the members of this class may be said to be, in the main, dependent upon their own individual efforts, so that, in this respect, they differ widely from the pteropods, whose locomotions are brought about by winds driving them along the surface of the water on which they float.

Some gasteropods are terrestrial, air-breathing animals, though by

far the greater number are aquatic, and breathe by means of gills. But being all of them, as Prof. Owen says, "endowed with power to attain, subdue, and devour organic matter, dead and living," we find their nervous system not only better developed, more complex and concentrated, but also in relation with more highly-evolved organs of special sense and exploration. It offers considerable variations in its general arrangement, especially as regards relative positions of ganglia, though these modifications are, to a great extent, referable to differences in the outward configuration of the body.

Some of the differences in external form which are to be met with among gasteropods are well illustrated by the limpet or the chiton, as compared with the snail. Here differences in form coexist with differences in habit, so that we almost necessarily meet with notable variations in the disposition of the principal parts of the nervous system.

In the limpet we find that the two small cerebral ganglia (Fig. 10, *a*) are widely separated from one another, and lie at the side of the œsophagus. Each receives a rather large nerve from one of the tentacles, and a smaller optic nerve. A commissure connects these cerebral ganglia above the œsophagus with one another, while each of them is also in relation by means of two descending commissures with a series of four connected ganglia forming a transversely-arranged row beneath the œsophagus. Of these the two median ganglia (*B*) correspond with the pedal, while the two external (*C*) correspond with the branchial ganglia, though they are here separated from one another by an immensely wide interval.

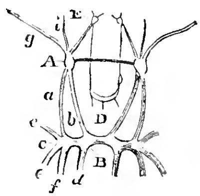


Fig. 10.—Nervous System of the Common Limpet.

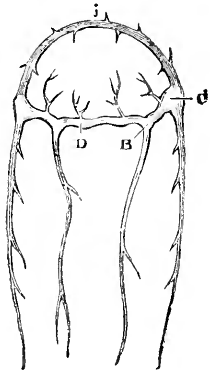


Fig. 11.—Nervous System of *Chiton marmoratus*.

However small and undeveloped the duplex brain of the limpet may be, this organ exists in an even more rudimentary state in some other gasteropods. Thus, in the chiton, which is a close ally of the limpet, and about the most simply organized of all the gasteropods, there are neither tentacles nor eyes, and, as a consequence of this,

there are (Fig. 11) no supra-œsophageal ganglia. There is nothing, in fact, to which the term brain can be appropriately applied.

But, if we turn now to the much more active snail, we find the nervous system existing in a more developed and concentrated form. There is (Fig. 12, *l*) a large ganglionic mass situated over the œsophagus, each half of which receives a considerable bundle of nerve-fibres (*f*) from the eye (*b*) of the smaller side, which is situated at the tip of the larger tentacle. It also receives another bundle of nerves (*k*)

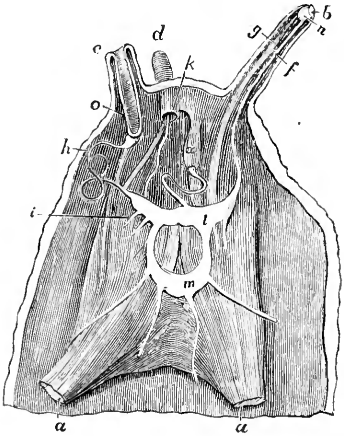


FIG 12.—HEAD AND NERVOUS SYSTEM OF THE COMMON SNAIL.

from the small tentacle on each side, which has in all probability a tactile function. The auditory vesicles are here in a new position. They are in immediate relation with the posterior aspect of these ganglia constituting the brain, though in other gasteropods they are, as in bivalve *Mollusca*, found to be connected with the pedal ganglia. That gasteropods are endowed with a rudimentary sense of smell is now generally admitted by naturalists, though hitherto they have been unable to locate this endowment in any particular organ or surface-region.

The brain of the snail is connected, by means of a triple cord or commissure on each side of the œsophagus, with a still longer double ganglionic mass (*m*). This latter body, situated beneath the œsophagus, represents the pair of pedal and the pair of branchial ganglia of the bivalve *Mollusca*. Here nerves are received from the integument and given off to the muscles of the foot, while they are also received and given off from the respiratory and other organs.

In the nautilus and some other representatives of the next class, *Cephalopoda*, the nervous system attains a development only slightly in advance of that met with among the highest gasteropods, though in the active and predaceous cuttle-fish, and in its near ally, the octopus, we find the nervous system presenting the highest development to be met with among the sub-kingdom *Mollusca*.

One of the most striking characteristics of the principal nerve-centres of the cuttle-fish is the fact of the existence of a very large optic ganglion (Fig. 13, 2), in connection with a well-developed eye, on each side. Each optic lobe, according to Lockhart Clarke, is "as large as the rest of the cephalic ganglia on both sides taken together." From each of these lobes an optic peduncle passes inward to join a supra-œsophageal ganglionic mass, which bears on its surface a large bilobed ganglion (1), thought by Clarke to be homologous with the cerebral lobes of fishes. It is connected, by means of two short cords,

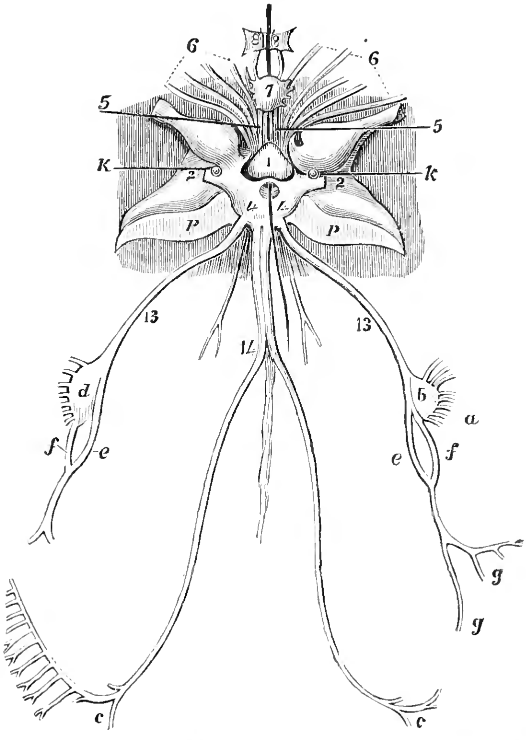


FIG. 13.—NERVOUS SYSTEM OF THE COMMON CUTTLE-FISH (*Sepia officinalis*).

with a much smaller bilobed ganglion, known as the pharyngeal (7). This double ganglion receives nerves from what are presumed to be the organs of taste and smell, and gives off nerves to the tongue and powerful parrot-like jaws with which the creature is provided.

The supra-œsophageal mass is connected, by cords at the sides of the œsophagus, with a very large ganglion lying beneath it (4), which is partially divided into an anterior and a posterior division. The anterior division is in relation, by means of large nerves (6), with the feet and tentacles. A commissure also unites it with the pharyngeal ganglion, so that the tentacles and arms are thus able to be brought

into correlated action with the jaws. The posterior portion of the sub-œsophageal mass receives nerves from, and also gives off nerves (14) to, the branchiæ and other viscera, as well as to the mantle (13, 13).

The auditory organs and their nerves are also connected with this branchial and pallial ganglion. These organs are lodged in the substance of the cartilaginous framework investing the nerve-ganglia—a structure which seems to answer to a rudimentary skull. The roots of the auditory nerves are probably principally in relation with the pallial portion of the branchio-pallial ganglion. The locomotions of these creatures are largely brought about by contractions of the pallial chamber, though these contractions of the mantle are also subservient to the respiratory function.

The share which the branchio-pallial ganglia take in bringing about and regulating the movements of the cuttle-fish would seem to explain the connection of the auditory nerves with them rather than with the homologues of the pedal ganglion, with which the auditory saccules are in relation in most other mollusks. But, whatever may be the precise explanation of the different connections of the auditory nerves in the cuttle-fish tribe, the fact remains that their connections are still away from the brain proper. They are, as in most other *Mollusca* and in those insects in which auditory organs are known to occur, in intimate relation with one of the principal motor centres.

This survey of some of the principal forms of the invertebrate brain, brief though it has been, should have sufficed to call attention to the following important facts and inferences:

1. That sedentary animals, though they may possess a nervous system, are often headless, and then have nothing answering to a brain.

2. That where a brain does exist, it is invariably a double organ. Its two halves may be widely separated from one another, though at other times they are fused into a single mass.

3. That the component or elementary parts of the brain in these lower animals are ganglia in connection with some of those special impressible parts or sense-organs, by means of which the animal is brought into harmony with its environment or medium.

4. That the sensory ganglia, which as an aggregate constitute the brain of invertebrate animals, are connected with one another both on the same and on opposite sides of the body, either by continuous growth or by means of commissures.

5. The size of the brain as a whole, or of its several parts, is strictly regulated by the development of the animal's special sense-organs. This is so, because, the more these impressible surfaces become elaborated and attuned to help in discriminating between numerous different external impressions, the larger are the ganglionic masses with which their nerves are in relation.

6. Of the several sense-organs and sensory ganglia whose activity

lies at the root of the intellectual and instinctive life (such as it is) of invertebrate animals, some are much more important than others. Two are notable for their greater proportional development, viz., tactile organs and visual organs. The former are soon outstripped in importance by the latter. The visual sense, indeed, and its related nerve-ganglia, attain an altogether exceptional development in the higher insects and mollusks.

7. The sense of taste and that of smell are developed to a much lower extent. It is even difficult to point to distinct organs or impressible surfaces as certainly devoted to the reception of impressions of this kind.

8. The sense of hearing is also developed to a very slight extent. No distinct sense-organ of this kind has been discovered, except in a few insects and in members of the sub-kingdom *Mollusca* It is, however, of no small interest to find that, where these organs do exist, the nerves issuing from them are not in direct relation with the brain, but are immediately connected with one of the principal locomotor nerve-centres of the body.

9. The associated ganglia representing the single or double brain are, in animals possessing a head, the centres in which all impressions from sense-organs, save those last mentioned (the auditory), are reflected on to appropriate groups of muscles. This reflection occurs either at once or after the stimulus has passed through other ganglia, whence it is passed along nerves to those groups or combinations of muscles whose simultaneous or successive contractions give rise to the organism's reply to such impressions. It may be easily understood, therefore, that in all such animals perfection of sense-organs, size of brain, and power of executing varied muscular movements, are intimately related to one another.

10. But a fairly parallel correlation also becomes established between these various developments and that of the internal organs. An increasing visceral complexity is gradually attained. Such increased visceral complexity carries with it the necessity for a further development of nervous communications. The several internal organs have to be brought into more perfect relation with the sensori-motor nervous system, and also with one another, for all joint actions in which two or more of them may be concerned.

11. In invertebrate animals the visceral system of nerves has, when compared with the rest of the nervous system, a greater proportional development than among vertebrate animals. Its importance among the *Invertebrata* is not dwarfed by the enormous development of the brain and spinal cord, which gradually declares itself among the *Vertebrata*.

12. Impressions emanating from the viscera and stimulating the organism to movements of various kinds, whether in pursuit of food or of a mate, would, therefore, have a proportionally greater impor-

tance as constituting part of the ordinary mental life of invertebrate animals. Movements thus initiated will be found to afford a basis for the development of many so-called instinctive acts.

PRENATAL AND INFANTILE CULTURE.[1]

BY DR. E. SEGUIN.

TO educate children for themselves is rare in Europe, and is considered rather quixotic. The youth of the people are merchantable commodities, soon to be credited to the party which puts its stamp upon them. Therefore, when they are worth having, they are picked up as eagerly as nuggets. Priests pretend to teach them to think, yet care only to impose upon them a belief which implies obedience to their craft; Kaisers claim their direction, not to elevate them, but to put them among their droves of subjects; *bourgeois* and manufacturers give them a minimum of instruction, just sufficient to insure their working dependence, and to qualify their own sons to be fed at the public expense; while the working-men themselves—demoralized by such examples—put their apprentices at menial employment, and cheat them out of their rightful technical training.

From this standpoint we consider European children as in four groups: those who receive no education; those who do not receive the education they need; those who receive an education which disqualifies them for work; and those whose education prepares them for work. From another point of view we saw that the European children enter the school younger, are trained longer, and are advanced further, than the Americans. As a consequence of this last contrast, we shall have less to say about the primary and grammar schools, and more about the infantile and the professional. We will leave the other consequences to issue naturally from observation.

1. THE CRADLE.—At the Vienna Exposition there was a *pavillon de l'enfant* (infant pavilion), a room replete with the necessaries of the nursery—and also with its superfluities—intended altogether to represent the unbounded wishes of a mother for her baby's comfort and happiness. This palace of luxurious nursing ought, in the estimation of the writer, to have been accompanied by a little manual of what is necessary to protect and to prepare life before nativity, in relation to what may be called fœtal education.

During this first period the feelings come mainly through reflex impressions from the mother, a process which not only lays the foundation of health and vitality, but which forms the deeper strata of

[1] Extracts from the Report of the Commissioners of the United States to the International Exhibition held at Vienna, 1873.

the moral dispositions and of the so-called innate ideas. The managers of the world "from behind the screens" know this, for it is at this time that they impose on plebeian women pilgrimages and ecstatic "*novenas*,"[1] and keep those of a higher class under more stringent impressions. Here, in Vienna, for instance, from the time of the Emperor Charles V. till quite recently, when an heir to the throne was expected, the empress was given in charge of a special director, who would regulate all her actions and surroundings, in view of commencing the course of submissive education of the contingent monarch, as early as the first evolution from the yolk-substance of the human egg during embryogenesis. Similar influence is now claimed for an object diametrically opposed to the degeneracy thus arrived at in the house of Hapsburg. It can be attained by counsels printed either in book-form or on scrolls, as are the sentences of the Koran. But, whatever may be the form given to this *magna charta* of the rights of the unborn, let it be found precisely where these rights ought to be kept most sacred, in the nursery; where their enforcement would protect the mother and elevate her function, at the same time that it would insure her fruit against the decay resulting from wrong prenatal impressions.

We know that a cold contact with the mother makes the fœtus fly to the antipode of its narrow berth; that a rude shock may destroy it, or originate life-long infirmities; that the emotion of fear in the mother is terror or fits within; that harsh words vibrate as sensibly in the liquor of the amnion as in the fluid of the labyrinth of the ear. For instance, when a mother has lulled her home-sorrows with strains of soothing music, her child, too often an idiot, shows wonderful musical proclivities amid the wreck of all the other faculties of his mind. For thirty-five years the writer has furnished his share of the facts, which abound in modern books on physiology, in support of this doctrine.

It is useless to give here the illustrations detailed in the report; but experienced physicians will testify that, when their hands receive a new-comer, they plainly read upon his features the dominant feelings and emotions of its mother during that intra-uterine education whose imprints trace the channel of future sympathies and abilities. Therefore, if it is noble work to educate or to cure the insane, the idiot, the hemiplegic, the epileptic, and the choreic, how much higher is the work of preventing these degeneracies in the incipient being, by averting those commotions which storm him in the holy region intended for a terrestrial paradise during the period of evolution! To teach *him* reverence toward the bearer of his race, to instruct *her* in the sacredness of bland and serene feelings during the Godlike creative process, is educating two generations at once—this is the highest education of the nursery.

[1] A nine days' season of prayer.

From this, the true cradle of mankind, let us look at that made for the baby. There was no end of cradles in the *pavillon de l'enfant;* and we may find more philosophy in them than the upholsterer intended to put there. Therein the infant will at first but continue his ovum-life; and for this the cradle must be fitted. Let us see. The head is bent, the extremities are drawn up, and the body shaped like a crescent. This attitude gives to the muscles the greatest relaxation, and to the cartilages, which cap the bones, the position most favorable to nutrition and growth. Generally, the baby rests on the right side, to free the heart from pressure and to facilitate its movements. In this mode of reclining, the left hemi-cerebrum will contain more blood than the right, which is compressed by the pillow. Attitudes concordant with the sleepy habits of the first months, and the activity of the mind during this long sleepiness, indicate the future preponderance of the mental operations of the left over the right side of the brain, the approaching superior nutrition and dexterity of the right over the left hand, and later even the causation of paralysis on the left. For the present, and for some time yet, the infant will live mainly in his sleep; during which, more than when awake, he will be seen angry, smiling, or thinking, even in his well-defined dreams.

How important it is, then, that the cradle be formed in accordance with these natural indications! A transitory abode between the basin and the bed, it should be a warm, soft, yet supporting recipient, ampler than the former, better defined in its shape than the latter, with curves less short than circles, and more varied than ovals. An egg, vertically split, would make two such cradles, or nests, suited either for child or bird.

But as soon as the nursling awakes to the world, and wants to be introduced to everything, his couch must be enlarged and enlivened, and must look more and more like a school and play-room. Otherwise it becomes a prison, whence, Tantalus-like, baby looks at his surroundings. Here is his first lesson of practical sociability. To see, and not be able to reach, to perceive images, with no possibility of seizing the objects, renders him impatient, fretful, or unconcerned, and opens an era of exaction upon others, or of diffidence of himself, or of indifference for any attainment, which unavoidably ends in immorality or incapacity, or in both. Viewed from this standpoint, these cradles, so varied, so elegant, so easy to keep clean, and to carry from the light of the window by day to the recess of the alcove at night—the best being of French and Austrian manufacture—are yet very imperfect in their bearing on education. Let us mark some of their shortcomings.

Little ones have an instinctive horror of isolation. Whoever studies them knows that when they awake they look not, at first, with staring eyes, but with searching hands; they seek not for sights, but for contacts. This love of contact, whence results the primary

education of the most general sense, the touch, is ill-satisfied with the uniformity of the materials at hand, as exemplified at Vienna or Paris. (In November last I saw a similar exhibition, a *pavillon de l'enfant*, in the Champs Élysées, but it was no improvement on that of the Prater.)

In this respect, the child of poor people fares better, having the opportunity of amusing himself for hours in experiencing the rude or soft, warm or cold, contacts of his miscellaneous surroundings; whereas the hand of the offspring of the rich finds all around the sameness of smooth tissues, which awake in his mind no curiosity; he calls for some one to amuse him, gets first angry, then indifferent, and does not improve the main and surest sense of knowledge, his touch.

But soon other senses are awakened: audition—of which hereafter—and vision, for the enjoyment of which the cradle becomes a kind of theatre. For a mother must be very destitute or despondent who does not try to enliven it with some bright things laid on, or flapping above. One may benevolently smile at the extravagancies of colors and patterns intended to express this feeling, but these exaggerations must also give a serious warning.

Physiologically viewed, this is a grave matter. The form of the cradle demands fitness; its ornamentation requires a more extended knowledge. When planning it, a mother must remember that the fixity of the eye upon any object—particularly upon a bright one, and more so if that object is situated upward and sideways from the ordinary range of vision—and through the eye the fixedness of the mind while the body is in a state of repose, constitute a concurrence of conditions eminently favorable to the production of hypnotism, and its terrible sequels, strabismus and convulsions. Hypnotism, which, when unsuspected, is not controlled, is often mistaken for tranquil happiness or natural sleep.

Psychologically viewed, the decoration of the cradle is of equal moment. To surround an infant with highly wrought or colored figures, often grotesque, or at least untrue to Nature, may, by day, attract more attention than his faculties of perception can safely bestow; hence fatigue of the brain, or worse; but it will, by night, evoke other than the perceptive and rational powers, for, when the lights and shadows of dusk alter all the forms and deepen every color, the faculty of imprinting images being led astray, it photographs distorted imprints from confused, often moving, sometimes rustling, ornaments. In this way the mind is made the subject of hallucinations, which it accepts as objective, without inquiring into their causes, till it comes to the fatal *credo quia absurdum* (I believe, because it is absurd). The seeds of most of the insanities are sown at or before this time.

These were the first impressions that forced themselves upon my

mind in the *pavillon de l'enfant.* Here is, in a few words, a *résumé* of them: Paucity of the material upon which the inexperienced yet inquisitive baby can exercise, with interest and profit, his sense of touch; profusion, bad taste, and dangerous disposition of the objects which speak to the eye, if not always with the intention, at least with the almost uniform result, of giving wrong or dangerous impressions.

Attention was next called to what had been done, and to what had been left undone, for the cultivation or the satisfaction of the other senses of the infant. But here it was soon perceived that our inquiries went beyond the sphere of what was exhibited. There were plenty of Farina's and Rimmel's volatilities, some of Alexander's, Debain's, or Smith's sighing accordeons, but no means of cheering and educating the nascent yet already inquisitive senses. Further examination showed that the perfumes were there as an attenuation and the music as a distraction, and both intended for other senses than the infant's. From these and other omissions it was concluded that nursery arrangements are as yet intended rather for the mother's and nurse's comfort than for the baby's improvement.

2. The Crèche.—This *pavillon de l'enfant* ought to contain at least ene model *crèche.*

Crèche is the French name of the public nursery where working-women leave their little ones in the morning, and whence they bring them home at night. The *crèche!* Horrid necessity! Beginning of the communistic inclined plane upon which those who pay and do not receive rents slide with a fearful rapidity; yet a kind institution for those already fallen into the gulf. Since, therefore, *crèches* must be, their latest improvements should have been represented at the Vienna Exhibition next to the appliances of the most luxurious nursing. There could have been tested the action of colors, of light, and its various attributes, on the organ of vision; the influence of varied sounds, of harmonies and melodies on the virgin audition, the mind, and the sympathetic centres; the power of primary perceptions to awaken first ideas, to impel to determinations of the will, and to raise or calm the various passions; the effects of diet upon those passions; the effect of modification of food and digestion; the influence of rest and sleep on the body's temperature, on the pulse and respiration; the influence of the artificial, the moist, or the dry heat of the nursery on the too precocious development of the nervous centres, and, subsequently, on the prevalence of chronic or acute meningitis, diphtheria, and croup; besides many other problems whose solution depends on the early study of phenomena which can be found in the *crèche* as surely as the flower in the bud. There, better than anywhere else, they may be studied with profit to all parties. Let us bear in mind that the rich man can never flatter himself that he does a gratuitous charity, since from its poor recipient comes many

times its worth in useful experience, directly benefiting the would-be benefactor. We do not overlook the fact that many mothers, particularly among those both educated and fruitful, pay the closest attention to these questions, and become expert therein, but, as they lack the means of record and transmission of their observations, their experience dies, so to speak, with each generation. Hence the nursing of babies continues to be a work of devotion, but does not become the coördinated and progressive art it ought to be in well-organized *crèches* open to criticism in public exhibitions. Thus in Vienna, at least, an opportunity was lost.

PROFESSOR HUXLEY'S LECTURES.[1]

I.

THE THREE HYPOTHESES OF THE HISTORY OF NATURE.

WE live and form part of a system of things of immense diversity and perplexity, which we call Nature, and it is a matter of the deepest interest to all of us that we should form just conceptions of the constitution of that system and of its past history. With relation to this universe, man is, in extent, little more than a mathematical point; in duration, but a fleeting shadow. He is a reed shaken in the winds of force; but, as Pascal long ago remarked, although a reed, he is a thinking reed, and, in virtue of that wonderful capacity of thought, he has a power of framing to himself a symbolic conception of the universe, which, although doubtless highly imperfect, and although wholly inadequate as a picture of that great whole, is yet sufficient to serve him as a guide-book in his practical affairs. It has taken long ages of accumulated and often fruitless labor to enable man to look steadily at the shifting scenes, phantasmagoria of Nature, to notice what is fixed among her fluctuations, and what is regular among her apparent irregularities; and it is only comparatively lately, within the last few centuries, that there has emerged the conception of a pervading order and a definite course of things, which we term the course of Nature.

But out of this contemplation of Nature, and out of man's thought concerning her, there has in these later times arisen that conception of the constancy of Nature to which I have referred, and which at length has become the guiding conception of modern thought. It has ceased to be almost conceivable to any person who is familiar with

[1] The first of three lectures on "The Direct Evidence of Evolution," delivered at Chickering Hall, New York, September 18th. From the report of the *New York Tribune*, carefully revised by Prof. Huxley.

the facts upon which that conception is based, that chance should have any place in the universe, or that events should follow anything but the natural order of cause and effect. We have come to look upon the present as the child of the past and as the parent of the future; and, as we have excluded chance from any share or part in the order of things, so in the present order of Nature men have come to neglect, even as a possibility, the notion of any interference with that order. And, whatever may be men's speculative notions upon those points, it is quite certain that every intelligent person guides his life and risks his fortune upon the belief that the order of Nature is constant, and the relation of cause to effect unchanged.

In fact, there is no belief which we entertain which has so complete a logical basis as that to which I have just referred. It tacitly underlies every process of reasoning; it is the foundation of every act of the will. It is based upon the broadest induction, and it is verified by the most constant, regular, and universal of deductive processes. But we must recollect that any human belief, however broad its basis, however defensible it may seem, is, after all, only a probable belief, and that our broadest generalizations are simply statements of the highest degrees of probability. Though we are quite clear about the constancy of Nature at the present time, and in the present order of things, it by no means follows necessarily that we are justified in expanding this generalization into the past, and in denying absolutely that there may have been a time when Nature did not follow a fixed order, when the relations of cause and effect were not definite, and when external agencies did not intervene in the general course of Nature. Cautious men will admit that such a change in the order of Nature may have been possible, just as a very candid thinker may admit that there may be a world in which two and two do not make four, and in which two straight lines do not inclose a space. In fact, this question with which I have to deal in the three lectures I shall have the honor of delivering before you, this question as to the past order of Nature, is essentially an historical question, and it is one that must be dealt with in the same way as any other historical problem.

I will, if you please, in the first place, state to you what are the views which have been entertained respecting the order of Nature in the past, and then I will consider what evidence is in our possession bearing upon these views, and by what light of criticism that evidence is to be interpreted. So far as I know, there are only three hypotheses which ever have been entertained, or which well can be entertained, respecting the past history of Nature.

Upon the first of these the assumption is, that the order of Nature which now obtains has always obtained; in other words, that the present course of Nature, the present order of things, has existed from all eternity. The second hypothesis is, that the present state of

things has had only a limited duration, and that at some period in the past the state of things which we now know (substantially, though not, of course, in all its details) arose and came into existence without any precedent condition from which it could have naturally proceeded. The third hypothesis also assumes that the present order of Nature has had but a limited duration, but it supposes that the present order of things proceeded by a natural process from an antecedent order, and that from another antecedent order, and so on; and on this hypothesis the attempt to fix any limit at which we could assign the commencement of this series of changes is given up. I am very anxious that you shall realize what these three hypotheses actually mean; that is to say, what they involve, if you can imagine a spectator to have been present during the period to which they refer. On the first hypothesis, however far back in time you place that spectator, he would have seen a world essentially, though not perhaps in all its details, similar to that which now exists. The animals which existed would be the ancestors of those which now exist, and like them; the plants in like manner would be such as we have now; and the supposition is that, at however distant a period of time you place your observer, he would still find mountains, plains, and waters, with animal and vegetable products flourishing upon them and sporting in them just as he finds now. That view has been held. It was a favorite fancy of antiquity, and has survived toward the present day. It is worthy of remark that it is an hypothesis which is not inconsistent with what geologists are familiar with as the doctrine of Uniformitarianism. That doctrine was held by Hutton, and in his earlier days by Lyell. For Hutton was struck with the demonstration of astronomers that the perturbations of the planetary bodies, however great they may be, yet sooner or later right themselves, and that the solar system contained within itself a self-adjusting power by which these aberrations were all brought back to an equilibrium.

Hutton imagined that something of the same kind may go on in the earth, although no one recognized more clearly than he the fact that the dry land is being constantly washed down by rain and rivers and deposited in the sea, and that thus in a certain length of time, greater or shorter, the inequalities of the earth's surface must be leveled, and its high lands brought down to the sea. Then, taking into account the internal forces of Nature, by which upheavals of the sea-bottom give rise to new land, he thought that these operations might naturally compensate each other, and thus, for any assignable time, the general features of the earth might remain what they are. And, inasmuch as there need be no limit under these circumstances to the propagation of animals and plants, it is clear that the logical development of this idea might lead to the conception of the eternity of the world. Not that I mean to say that either Hutton or Lyell held this conception—assuredly not; they would have been the first to repu-

diate it. But, by the arguments they used, it might have been possible to justify this hypothesis.

The second hypothesis is that to which I have referred as the hypothesis which supposes that the present order of things had at some no very remote time a sudden origin, so that the world, such as it now is, arose. That is the doctrine which you will find stated most fully and clearly in the immortal poem of John Milton, the English "Divina Commedia," "Paradise Lost." I believe it is largely to the influence of that remarkable work, combined with daily teachings to which we have all listened in our childhood, that this hypothesis owes its general wide diffusion as one of the current beliefs of English-speaking people. If you turn to the seventh book of "Paradise Lost" you will find there stated the hypothesis to which I refer, which is briefly this: That this visible universe of ours made its appearance at no great distance of time from the present day, and that the parts of which it is composed made their appearance in a certain definite order in the space of six natural days, in such a manner that in the first of these days light appeared; in the second, the firmament or sky separated the water above from the water beneath it; on the third day the waters drew away from the dry land, and upon it a varied vegetable life similar to that which now exists made its appearance; that the fourth day was devoted to the apparition of the sun, the stars, the moon, and the planets; that on the fifth day aquatic animals originated within the waters; that on the sixth day the earth gave rise to our four-footed terrestrial creatures, and to all varieties of terrestrial animals except birds, which had appeared on the preceding day; and, finally, that man appeared upon the earth, and the work of fashioning the universe was finished. John Milton, as I have said, leaves no doubt whatever as to how, in his judgment, these marvelous processes occurred. I doubt not that his immortal poem is familiar to all of you, but I should like to recall one passage to your minds, in order that I may be justified in what I have said regarding the perfectly concrete, definite conception which Milton had respecting the origin of the animal world. He says:

> "The sixth, and of creation last, arose
> With evening harps and matin; when God said,
> 'Let the earth bring forth soul living in her kind,
> Cattle and creeping things, and beast of the earth,
> Each in their kind.' The earth obeyed, and straight
> Opening her fertile womb, teemed at a birth
> Innumerous living creatures, perfect forms,
> Limbed and full-grown; out of the ground uprose,
> As from his lair, the wild beast, where he wons
> In forest wild, in thicket, brake, or den;
> Among the trees in pairs they rose, and walked;
> The cattle in the fields and meadows green;
> Those rare and solitary, these in flocks

Pasturing at once, and in broad heards upsprung.
The grassy clods now calved; now half appears
The tawny lion, pawing to get free
His hinder parts, then springs, as broke from bonds,
And rampant shakes his brinded mane; the ounce,
The libbard, and the tiger, as the mole
Rising, the crumbled earth above them threw
In hillocks; the swift stag from underground
Bore up his branching head; scarce from his mould
Behemoth, biggest born of earth, upheaved
His vastness; fleeced the flocks and bleating rose
As plants; ambiguous between sea and land,
The river-horse and scaly crocodile.
At once came forth whatever creeps the ground,
Insect or worm."

There is no doubt as to the meaning of this statement, or as to what a man of Milton's genius expected would have been actually visible to one who could witness the process of the origination of living things.

The third hypothesis, or the hypothesis of evolution, supposes that at any given period in the past we should meet with a state of things more or less similar to the present, but less similar in proportion as we go back in time; that the physical form of the earth could be traced back in this way to a condition in which its parts were separated, as little more than a nebulous cloud making part of a whole in which we should find the sun and the other planetary bodies also resolved; and that, if we traced back the animal world and the vegetable world, we should find preceding what now exist animals and plants not identical with them, but like them, only increasing their differences as we go back in time, and at the same time becoming simpler and simpler, until finally we should arrive at that gelatinous mass which, so far as our present knowledge goes, is the common foundation of all life.

The hypothesis of evolution supposes that in all this vast progression there would be no breach of continuity, no point at which we could say "This is a natural process," and "This is not a natural process," but that the whole might be compared to that wonderful series of changes which may be seen going on every day under our eyes, in virtue of which there arises, out of that semifluid, homogeneous substance which we call an egg, the complicated organization of one of the higher animals. That, in a few words, is what is meant by the hypothesis of evolution.

I have already suggested that in dealing with these three hypotheses, in endeavoring to form a judgment as to which of them is the more worthy of belief; or whether none is worthy of belief—and our condition of mind should be that suspension of judgment which is so difficult to all but trained minds—we should be indifferent to all *a*

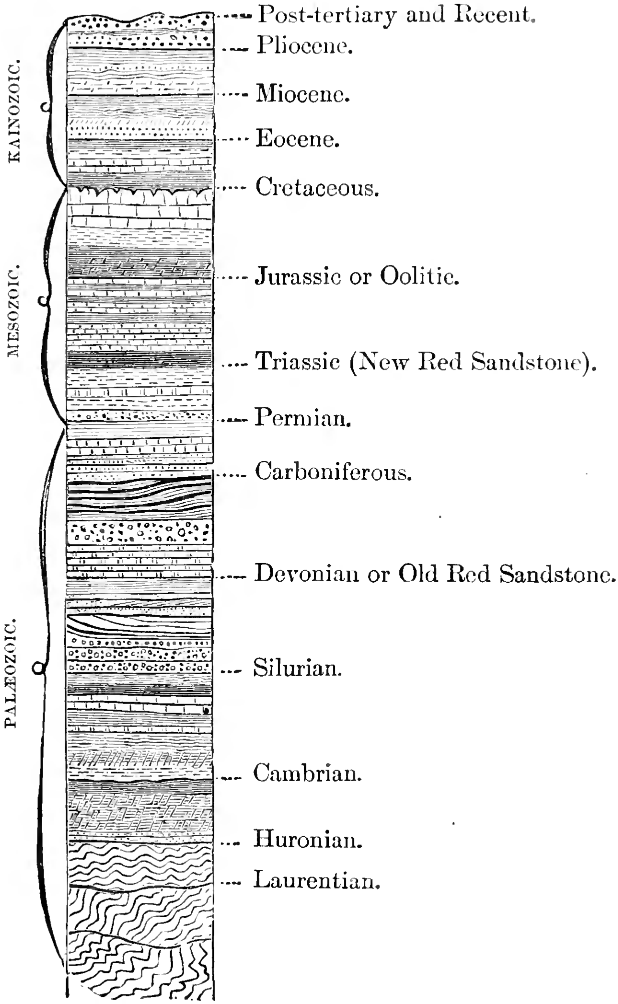
priori considerations. The question is a question of fact, historical fact. The universe has come into existence somehow or other, and the question is, whether it came into existence in one fashion, or whether it came into existence in another; and, as an essential preliminary to our further discussion, permit me to say two or three words as to the nature of historical evidence, and the kinds of historical evidence. The evidence as to the occurrence of any fact in past time is of one or two kinds, which, for convenience' sake, I will speak of on the one hand as testimonial evidence, and on the other as circumstantial evidence. By testimonial evidence I mean human testimony; and by circumstantial evidence I mean evidence which is not human testimony. Let me illustrate by a familiar figure what I mean by these two kinds of evidence, and what is to be said respecting their value:

Suppose that a man tells you that he saw a person strike another and kill him; that is testimonial evidence of the fact of murder. But it is possible to have circumstantial evidence of the fact of murder; that is to say, you may find a man dying with a wound upon his head having exactly the form and character of the wound which is made by an axe, and, with due care to take surrounding circumstances into account, you may conclude with the utmost certainty that the man has been murdered—is dying in consequence of the violence inflicted by that implement. We are very much in the habit of considering circumstantial evidence as of less value than testimonial evidence, and it may be in many cases, where the circumstances are not perfectly clear and perfectly intelligible, that it is a dangerous and uncertain kind of evidence; but it must not be forgotten that in many cases it is quite as good as testimonial evidence, and that not unfrequently it is a great deal better than testimonial evidence. For example, take the case to which I referred just now. The circumstantial evidence is better and more convincing than the testimonial evidence, for it is impossible, under the circumstances that I have mentioned, to suppose that the man had met his death from any cause but the violent blow of an axe wielded by another man. The circumstantial evidence in favor of a murder having been committed, in that case, is as complete and as convincing as evidence can be. It is evidence which is open to no doubt and no falsification. But the testimony of the witness is open to multitudinous doubts. He may have been mistaken. He may have been actuated by malice. It has constantly happened that even an accurate man has declared a thing has happened in this, that, or the other way, when a careful analysis of the circumstantial evidence has shown that it did not happen in that way, but in some other way.

Now we must turn to our three hypotheses. Let me first direct your attention to what is to be said about the hypothesis of the eternity of this state of things in which we now are. What will first strike you is, that that is an hypothesis which, whether true or false, is not capable of verification by evidence; for, in order to secure testi-

mony to an eternity of duration, you must have an eternity of witnesses or an infinity of circumstances, and neither of these is attainable. It is utterly impossible that such evidence should be carried beyond a certain point of time, and all that could be said at most should be that there was nothing to contradict the hypothesis. But when you look, not to the testimonial evidence—which might not be good for much in this case—but to the circumstantial evidence, then you find that this hypothesis is absolutely incompatible with that circumstantial evidence, and the evidence is of so plain and so simple a character that it is impossible in any way to escape from the conclusions which it forces upon us.

IDEAL SECTION OF THE CRUST OF THE EARTH.



You are, doubtless, all aware that the crust of the earth, the superficial part of the earth, is not of an homogeneous character, but that it is made up of a number of beds or strata, the titles or the principal groups of which are placed upon the accompanying diagram—beds of sand, beds of stone, beds of clay, of slate, and of various other materials.

On further examination, it is found that these beds of solid material are of exactly the same nature as these which are at present being formed under known conditions at the surface of the earth; that the chalk, for example, which forms a great part of the Cretaceous formation in some parts of the world, is identical in its physical and chemical characters, or practically so, with a substance which is now being formed at the bottom of the Atlantic Ocean, and covers an enormous area; that other bodies of rock are comparable with the sands which are being formed upon sea-shores, packed together, and so on. Thus it comes to be certain that, omitting rocks of igneous origin, all these beds of stone, of which a total of not less than seventy thousand feet is known, have been deposited and formed by natural agencies, either out of the waste and washing of the dry land, or else as the product of plants and animals. Now, these rocks or strata are full of the remains of animals and plants. Countless thousands of species of animals and plants, as perfectly recognizable as those which you meet with in museums at the present day, or as the shells and remains which you pick up upon the beach—countless thousands of species of these creatures have been imbedded in the sand or mud, or limestone, just as they are being imbedded now. They furnish us with a record, the general nature of which cannot be subject to any misinterpretation, as to the kind of things that have lived upon the surface of the earth during the time that is registered by this great thickness of stratified rock. The most superficial study of these remains shows us that the animals and plants which live at the present time have had only a temporary duration; that you will find them and such as they are now, for the most part, only in those uppermost of the strata called Tertiary. As you go back in time their places are taken by other forms as numerous and diversified, but different, and you will find yet others different from the Cretaceous or Tertiary, and from those of the present day, and so on, as you go further and further back. Thus, the circumstantial evidence absolutely negatives the conception of the eternity of the present condition of things. We can say with certainty that such has not been the course of Nature. We can say with certainty that the present condition of things has existed for a comparatively short period; and that, so far as animal and vegetable nature are concerned, it has been preceded by a different condition of things. We can pursue this evidence until we reach the lowest of stratified rocks, in which we lose the indications of life altogether. The hypothesis of the eternity of the present condition of things may, therefore, be put out of court.

We now come to what I may call Milton's hypothesis—the hypothesis that the present condition of things has endured for a comparatively moderate time, and at the commencement of that time came into existence within the course of six days. I doubt not that it may have excited some surprise in your minds that I should have spoken of this as Milton's hypothesis, rather than that I should choose the terms which are much more familiar to you, such as "the doctrine of creation," or "the Biblical doctrine," or "the doctrine of Moses," all of which denominations, as applied to the hypothesis to which I have just referred, are certainly much more familiar to you than the title of the Miltonic hypothesis. But I have had what I cannot but think are very weighty reasons for taking the course which I have pursued. For example, I have discarded the title of the hypothesis of creation, because my present business is not with the question as to how Nature has originated, as to the causes which have led to her origination, but as to the manner and order of the appearance of natural objects. Our present inquiry is not why the objects which constitute Nature came into existence, but when they came into existence, and in what order. This is a strictly historical question, a question as completely historical as that about the date at which the Angles and the Jutes invaded England. But the other question about creation is a philosophical question, and one which cannot be solved or even approached by the historical method. What we want to know is, whether the facts, so far as they are known, afford evidence that things arose in the way described by Milton, or not; and, when that question is settled, it will be time enough to inquire as to the causes of their origination.

In the second place, I have not spoken of this doctrine as the Biblical hypothesis. It is quite true that persons as diverse in their general views as Milton the Protestant and the celebrated Jesuit Father Suarez, each read in the first chapter of Genesis the interpretation adopted by Milton. It is quite true that that interpretation, unless I mistake, is that which has been instilled into every one of us in our childhood; but I do not for one moment venture to say that it can properly be called the Biblical doctrine. In the first place, it is not my business to say what the Hebrew text contains, and what it does not; in the second place, were I to say that this is the Biblical hypothesis, I should be met by the authority of many eminent scholars, to say nothing of men of science, who in recent times have absolutely denied that this doctrine is to be found in Genesis at all. If we are to listen to them, we must believe what seems so clearly defined in Genesis—as if very great pains had been taken so that there should be no possibility of mistake—is not the meaning of the text at all. The account is divided into periods that we may make just as long as convenience requires. We are also to understand that it is consistent with that phraseology to believe that plants and animals may have been evolved by natural processes, lasting for millions of years, out

of similar rudiments. A person who is not a Hebrew scholar can only stand by and admire the marvelous flexibility of a language which admits of such diverse interpretations.

Assuredly, in the face of such contradictory authority upon matters upon which he is competent to form no judgment, he will abstain from giving any opinion, as I do. In the third place, I have carefully abstained from speaking of this as a Mosaic doctrine, because we are now assured upon the authority of the highest critics, and even of dignitaries in the Church, that there is no evidence whatever that Moses ever wrote this chapter, or knew anything about it. You will understand that I give no opinion—it would be an impertinence upon my part to volunteer an opinion upon such a subject. But, that being the state of opinion among the scholars and the clergy, it is well for us the laity, who stand outside, to avoid entangling ourselves in such a vexed question. So, as happily Milton leaves us no conceivable ambiguity as to what he means, I will continue to speak of the opinion in question as the Miltonian hypothesis.

Now we have to test that hypothesis. For my part, I have no prejudice one way or the other. If there is evidence in favor of this view, I have no sort of theoretical difficulties in the way of accepting it, but there must be evidence. We scientific men get an awkward habit—no, I won't call it that, for it is a valuable habit—of reasoning, so that we believe nothing unless there is evidence for it; and we have a way of looking upon belief which is not based upon evidence, not only as illogical, but as immoral. We will, if you please, test this view in the light of facts, for by what I have said you will understand that I don't propose to discuss the question of what testimonial evidence is to be adduced in favor of this view. If those whose business it is to judge are not at one as to the authenticity of the document, or as to the facts to which it bears witness, the discussion of testimonial evidence is superfluous. But one regards this less because the circumstantial evidence, if carefully considered, leads to the conclusion that the hypothesis is altogether inadequate, and cannot be sustained. And the considerations upon which I base that conclusion are of the simplest possible character. Whatever the flexibility of interpretation of the statement on which Milton's hypothesis is based, it is quite impossible to deny that it contains assertions of a very definite character relating to the succession of living forms. It is stated that plants, for example, made their appearance upon the third day, and not before. And you will understand that what was meant by plants are plants which now live—the trees and shrubs which we now have. One of two things—either the existing plants have been the result of a separate origination of which we have no record or ground for supposition, or else they have arisen by process of evolution from the original stock. And, in the second place, it is clear that there was no animal life before the fourth day, and that on

the fourth day marine animals and birds appeared. And it is further clear that terrestrial life made its appearance upon the sixth day, and not before. Hence, it follows that, if in the large mass of circumstantial evidence as to what really has happened in the past history of the globe—if in that we find down to a certain point indications of the existence of terrestrial animals, it is perfectly certain that all that has taken place since that time must be referred to the sixth day.

In this great Carboniferous formation whence America has derived so vast a proportion of her actual and potential wealth, in that formation and in the beds of coal which are formed from the vegetation of that period, we find abundant evidence of the existence of terrestrial animals. They have been described not only by European naturalists, but by your own naturalists. There are to be found in the coal of your own coal-fields numerous insects allied to our cockroaches. There are to be found there spiders and scorpions of large size, and so similar to existing scorpions that it requires the practised eye of the naturalist to distinguish them. Inasmuch as these things can be proved to have been alive in the Carboniferous epoch, it is perfectly clear that, if the Miltonic account is correct, the huge mass of rocks extending from the middle of the Palæozoic formations to the end of the series must belong to the day or period which is termed by Milton the sixth day of the creation. But, further, it is expressly stated that aquatic animals took their origin upon the fifth day, and did not exist before; hence all formations in which aquatic animals can be proved to exist, and which therefore lived at the time these formations were deposited, must have been deposited during the time of the period which Milton speaks of as the fifth day. But there is absolutely no fossiliferous rock in which you do not find the remains of marine animals. The lowest forms of life in the Silurian are marine animals, and, if the view which is entertained by Principal Dawson and Dr. Carpenter respecting the nature of the *Eozoön* be correct, if it is true that animal remains exist at a period as far antecedent to the deposit in the coal as the coal is from us, at the bottom of the series of stratified rocks in the Laurentian strata, it follows plainly enough that the whole series of stratified rocks, if they are to be brought into harmony with Milton at all, must be referred to the sixth day, and we cannot hope to find the slightest trace of the work of the other days in our stratified formations. When one comes to consider this, one sees how absolutely futile are the attempts that have been made to run a parallel between the story told by the stratified rocks as we know them and the account which Milton gives of it. The whole series of stratified rocks must be referred to the last two periods, and neither the Carboniferous nor any other formation can afford evidence of the work of the third day. Not only is there this objection to any attempt to run a parallel between the Miltonic account and the actual facts, but there is a further difficulty. In the

Miltonic account the order in which animals should have made their appearance in the stratified rock would be this: Fishes, including the great whales, and birds; after that, all varieties of terrestrial animals. Nothing could be further from the facts as we find them. As a matter of fact we know of not the slightest evidence of the existence of birds before the Jurassic and perhaps the Triassic formations.

If there were any parallel between the Miltonic account and the circumstantial evidence, we ought to have abundant evidence of the existence of birds in the Devonian, the Silurian, and the Carboniferous rocks. I need hardly tell you that this is not the case, and that not a trace of birds makes its appearance until the far later period which I have mentioned.

And again, if it be true that all varieties of fishes and the great whales, and the like, made their appearance on the fifth day, then we ought to find the remains of these things in the older rocks—in those which preceded the Carboniferous epoch. Fishes, it is true, we find, and numerous ones; but the great whales are absent, and the fishes are not such as now live. Not one solitary species of fish now in existence is to be found there, and hence you are introduced again to the dilemma that either the creatures which were created then, which came into existence the sixth day, were not those which are found at present, are not the direct and immediate predecessors of those which now exist; in which case you must either have had a fresh creation of which nothing is said, or a process of evolution; or else the whole story must be given up, as not only devoid of any circumstantial evidence, but contrary to that evidence.

I placed before you in a few words, some little time ago, a statement of the sum and substance of Milton's hypothesis. Let me try now to put before you as briefly the effect of the circumstantial evidence as to the past history of the earth which is written without the possibility of mistake, with no chance of error, in the stratified rocks. What we find is, that that great series of formations represents a period of time of which our human chronologies hardly afford us a unit of measure. I will not pretend to say how we ought to measure this time, in millions or in billions of years. Happily for my purpose, that is wholly unessential. But that the time was enormous, there is no sort of question.

It results from the simplest methods of interpretation, that all that is now dry land has once been at the bottom of the waters. Leaving out of view certain patches of metamorphosed rocks, certain volcanic products, it is perfectly certain that at a comparatively recent period of the world's history—the Cretaceous epoch—none of the great physical features which at present mark the surface of the globe existed. It is certain that the Rocky Mountains were not. It is certain that the Himalaya Mountains were not. It is certain that the Alps and the Pyrenees had no existence. The evidence is of the plainest pos-

sible character, and is simply this: We find raised up on the flanks of these mountains, elevated by the forces of upheaval which have given rise to them, masses of cretaceous rock which formed the bottom of the sea before those mountains existed. It is therefore perfectly clear that the elementary forces which gave rise to the mountains operated subsequently to the Cretaceous epoch; that the mountains themselves are largely made up of the materials deposited in the sea which once occupied their place. We meet as we go back in time with constant alternations of sea and land, of estuary and open ocean, and in correspondence with these alternations we meet with changes in the fauna and flora of the kind I have stated.

But no inspection of these changes gives us the slightest right to believe that there has been any discontinuity in natural processes. There is no trace of cataclysm, of great sweeping deluges or universal destructions of organic life. The appearances which were formerly interpreted that way have all been shown to be delusive as our knowledge has increased and as the blanks between the different formations have been filled up. It can now be shown that there is no absolute break between formation and formation, that there has been no sudden disappearance of all the forms of life at one time and replacement by another, but that everything has gone on slowly and gradually, that one form has died out and another has taken its place, and that thus by slow degrees one fauna has been replaced by another. So that, within the whole of the immense period indicated by these stratified rocks, there is assuredly—leaving evolution out of the question altogether—not the slightest trace of any break in the uniformity of Nature's operations, not a shadow of indication that events have followed other than their natural and orderly sequence.

That, I say, is the most natural teaching of the circumstantial evidence contained in the stratified rock. I leave you to consider how far by any ingenuity of interpretation, by any stretching of the meaning of language, it can be brought into the smallest similarity with that view which I have put before you as the Miltonic doctrine.

There remains the third hypothesis—what I have spoken of as the hypothesis of evolution; and I propose that in lectures to come we should consider that as carefully as we have considered the other two hypotheses. I need not say that it is quite hopeless to look for testimonial evidence of evolution. The very nature of the case precludes the possibility of such evidence. Our sole inquiry is, what foundation circumstantial evidence lends to that hypothesis, or whether it lends any, or whether it controverts it; and I should deal with the matter entirely as a question of history. I shall not indulge in the discussion of any speculative probabilities. I shall not attempt to show that Nature is unintelligible unless we adopt some such hypothesis: for anything I know about it, it may be the way of Nature to be unintelligible. She is often puzzling, and I have no reason to suppose she

is bound to fit herself to our notions; but I shall deal with the matter entirely from the point of view of history, and I shall place before you three kinds of evidence entirely based upon what we know of the forms of animal life which are contained in the series of stratified rock. I shall endeavor to show you that there is one kind of evidence which is neutral, which neither helps evolution nor is inconsistent with it. I shall then endeavor to show you that there is a second kind of evidence which indicates a strong probability in favor of evolution, but does not prove it; and, lastly, I shall endeavor to show that there is a third kind of evidence which, being as complete as any evidence which we can hope to obtain upon such a subject, and being wholly and entirely in favor of evolution, may be fairly called demonstrative evidence of its having occurred.

THE MOON'S INFLUENCE ON THE WEATHER.[1]

By Professor M. A. F. PRESTEL.

A SUDDEN and considerable fall of the barometer is of frequent occurrence; but to find a case identical with that of November 22, 1873, I had to search my journals for many years back. It is worthy of note that, in 1854, an equally sudden and considerable fall of the barometer took place here on the coast of the North Sea on precisely the same days as in 1873. According to observations made at Emden, the barometric column on November 21, 1873, at 6 A. M., was 762.3 millimetres, and it then fell steadily till 2 P. M. on the 22d, when it reached the minimum, 732.5 millimetres, and then it again began to rise. At 6 A. M. of November 21, 1854, the barometer stood 760.7 millimetres, and the mercurial column then steadily fell until 6 A. M., November 23d, when it was 734.7 millimetres; it then began to rise. The point to which I would call special attention is that, on the occasion of both of these great falls of the barometer, the position of the moon with respect to the earth was precisely the same. There was new moon at 3 A. M. of November 20, 1873, and at 8 A. M. of November 20, 1854; in 1873 the moon entered the southern lunistice at 3 A. M. on November 23d, and in 1854 at 6 A. M. of November 23d; in both years the moon's declination on November 23d was 27° south.

Still, the occurrence of storms and barometric minima over Northwestern Europe on November 22, 1873 and 1854, at the period of the lunistitia and of the new moon, might be merely accidental; but that it was not accidental is shown by sundry mutually corresponding phenomena in the atmosphere, which were observed during these two

[1] Translated from the German by J. Fitzgerald, A. M.

years. During the month of October, 1873, the average height of the barometric column was 757.1 millimetres, and for the same month in 1854 it was 757.2 millimetres; the barometric mean for the five days between the 22d and the 28th was, in 1873, 750.7 millimetres, and in 1854, 748.7 millimetres; the minimum was reached, in 1873, on October 23d, and in 1854 on October 25th, being in the former case 734.9 millimetres, and in the latter 734.5 millimetres. In 1873 the maximum was reached in the evening of October 28th—773.7 millimetres, and in 1854 at noon of the 28th—774.9 millimetres. The weather was also the same in both years from the 3d to the 7th, and from the 21st to the 27th of October. From the 5th to the 7th there were frequent and heavy falls of rain; on the 7th, in 1873, and on the 5th, in 1854, there were violent thunder-storms. On both years from the 21st to the 25th the atmosphere was in a state of violent disturbance, tne barometric column being very low. And here we may state that there was new moon at 11 A. M. on October 21, 1873, and at 9 P. M. on October 21, 1854; that in 1873 the southern lunistice occurred at 10 P. M. of the 26th, and in 1854 at 9 P. M. of the 26th; and that the moon's declination at the time was about 27° south.

Further, from the 13th to the 16th of November, 1873, the distribution of atmospheric pressure over Europe and the state of the weather were similar to what they were on the same days in 1854. The fearful ravages wrought by the storms in the Black Sea on the days between the 13th and the 16th of November, 1854 (the Crimean War being then in progress), will render those days ever memorable. The numerous shipwrecks in the sea of Azof, and the loss of English and French war-ships in the Black Sea on the 13th and 14th, showed how desirable and necessary a thing it was that there should be found some means of warning seafarers of the approach of storms. It was these disasters which gave occasion to the establishment of storm-signals. From the 13th to the 15th of November, 1873, after a period of calm, with high barometer over the greater part of Northwestern Europe, we find succeeding a similar barometric minimum, and a storm area advancing across the Mediterranean toward the Black Sea.

At any given point of the earth's surface the state of the weather always depends on the prevailing air-currents. The annual and the secular periodic changes of the oceanic and the atmospheric currents are repeated in the weather-changes. And on the phenomena which, however imperfectly, establish this periodicity, is based the universal belief that the moon has an influence on the weather. The researches and calculations which have been made by meteorologists to determine the periodicity of weather phenomena, and the influence of the moon upon the latter, have hitherto been fruitless, and this simply because the observations of single stations only have been taken into account. From observations made at one point it is impossible to

obtain decisive results as to secular periodic weather-changes, even though these observations were to be carried on for a hundred years or more. The terrestrial atmospheric currents, in their passage over the same portion of the earth's surface (whether this passage be periodic or not periodic), never take the same route, or have the same limits, and consequently the localities over which they pass on their return will happen to be at one time in the centre of the current, at another time more or less near to its northern or its southern edge.

Under these circumstances the state of barometer and of thermometer, the amount of precipitation, the force of the wind, etc., upon which these researches are based, must yield conflicting results. Some, however, have supposed that better results might be obtained by combining these quantities, and taking the mean of all the readings. This method quite does away with anomalies, it is true, but then the result has no specific value whatever, though the aim of all such researches must always be to determine the weather specifically. The periodicity of weather phenomena can only be determined by means of investigations carried on according to the geographical method, i. e., by studying these atmospheric phenomena in their continuity both as regards time and space.

As has been already said, the track of the storm of November 17th–23d lay over nearly the same regions of the northern hemisphere in 1873 and 1854. Had these air-currents taken a course only a few degrees more to the north or to the south, their existence and their identity would have been so ill determined by the barometer of a single locality that they might easily have been overlooked.

On the 28th of November, 1873, at 10 P. M., the barometer at Emden stood at 756.4 millimetres, and then kept on falling till the 30th, at 8 A. M., when it was 744.2 millimetres; after this it rose till at 10 P. M. it was 762.6 millimetres. This not very considerable fall of the barometer would not have deserved special notice, were it not followed on the evening of the 29th by a storm of some violence, which through the night became a hurricane. In 1854, at the same period of the year, the barometer underwent a similar change, only much greater. On November 27th, at 10 P. M., the height of the barometric column was 757 millimetres. It then fell, till on the 29th, at 2 P. M., it was 727.8 millimetres, when it began rising till it reached 757.9 millimetres at 8 A. M., on the 30th. The quantitative difference of barometric pressure at Emden on November 27th and 28th, between the years 1873 and 1854, is simply the result of the difference in the tracks of the storms, and the consequent distance of the place of observation from the storm-centre. At Thorshavn, between November 25th and 28th, in 1873, the barometric changes were precisely the same as had been observed at Emden on the same days in 1854. In 1873, at 9 P. M. of the 25th, the mercurial column at Thorshavn was 757.3 millimetres; on the 26th, at 8 A. M., it was 746.9 millimetres; on the 26th at 9 P. M.,

729.2 millimetres; on the 27th, at 8 A. M., 729.8 millimetres; on the 28th, at 8 A. M., 747.3 millimetres.

With the moon in a like position with respect to the earth, there occurred, December 15–18, 1873 and 1854, just as on the 21st and 22d of November, a sudden and great fall of the barometer, accompanied by a fearful storm. In 1873, on the evening of the 13th, and in 1854, on the morning of the 14th, the moon was in the descending node. The moon's declination in 1873, at 3 P. M. of the 15th, and in 1854 at 7 A. M. of the 16th, was 12° south. At Emden, in 1873, the barometer fell on the 15th and 16th, from 768 to 745 millimetres, or 23 millimetres. At Skudesnäs the fall on the 15th and 16th December amounted to 25 millimetres; at Stockholm, on the 16th, to 20 millimetres; at St. Petersburg, from the 15th to the 17th, to 30 millimetres. The track of the centre of this storm entirely agrees with that of the storm of November 14th–22d. At 1 A. M. of December 14th, we find at Washington, North Carolina, a barometric minimum of 744.2 millimetres, and by $7^{h.}$ $35^{m.}$ this had advanced as far as Halifax. Here, at the time specified, the barometer had fallen to 735 millimetres. On the 14th, at $4^{h.}$ $35^{m.}$, the barometric minimum had passed in a northeast direction over Newfoundland, crossing the Atlantic Ocean. At Thorshavn, where, on the 14th, at 8 A. M., the barometer had stood at 757.4 millimetres, it had on the morning of the 16th fallen to 731.9. At Aberdeen, the barometer on the morning of the 16th stood at 735 millimetres.

In 1854, on the morning of December 17th, the barometer at Emden showed 752.2 millimetres; it then fell till noon on the 18th, when it was 731.1 millimetres, and then began to rise again. At the beginning of the fall of the barometer, a storm from the southwest set in, which increased in force till it became a hurricane. The rain which fell during the storm amounted to 18.9 millimetres.

At Cologne, at $3^{h.}$ $41^{m.}$, December 18, 1854, the barometer showed 726.6 millimetres—a barometric minimum never before observed there since 1830.

In 1854 the track of the storm-centre traversed Northern France and Germany: thus, as on November 22d, it was more southerly than in 1873.

Such concordant atmospheric phenomena as these, when the moon occupies the same position relating to the earth, might be quoted at great length. *The moon, as it governs ebb and flow, so too determines oceanic currents, and, by means of these, atmospheric currents.* From this it follows that the influence of the moon upon that portion of the atmosphere which overlies the continents must be less than that upon the supra-oceanic atmosphere.—*Gaea.*

DIFFICULTIES OF DEVELOPMENT AS APPLIED TO MAN.[1]

By ALFRED RUSSEL WALLACE, F. R. S.

As my own knowledge of and interest in anthropology are confined to the great outlines, rather than to the special details of the science, I propose to give a very brief and general sketch of the modern doctrine as to the Antiquity and Origin of Man, and to suggest certain points of difficulty which have not, I think, yet received sufficient attention.

Many now present remember the time (for it is little more than twenty years ago) when the antiquity of man, as now understood, was universally discredited. Not only theologians, but even geologists, then taught us that man belonged altogether to the existing state of things; that the extinct animals of the Tertiary period had finally disappeared, and that the earth's surface had assumed its present condition, before the human race first came into existence. So prepossessed were even scientific men with this idea—which yet rested on purely negative evidence, and could not be supported by any arguments of scientific value—that numerous facts which had been presented at intervals for half a century, all tending to prove the existence of man at very remote epochs, were silently ignored; and, more than this, the detailed statements of three distinct and careful observers were rejected by a great scientific society as too improbable for publication, only because they proved (if they were true) the coexistence of man with extinct animals![2]

But this state of belief in opposition to facts could not long continue. In 1859 a few of our most eminent geologists examined for themselves into the alleged occurrence of flint implements in the gravels of the north of France, which had been made public fourteen years before, and found them strictly correct. The caverns of Devonshire were about the same time carefully examined by equally eminent observers, and were found fully to bear out the statements of those who had published their results eighteen years before. Flint implements began to be found in all suitable localities in the south of England, when carefully searched for, often in gravels of equal antiquity with those of France. Caverns, giving evidence of human occupation

[1] From the opening address of Mr. Wallace, as President of the Biological Section of the British Association for the Advancement of Science, given at its recent meeting in Glasgow.

[2] In 1854 (?) a communication from the Torquay Natural History Society, confirming previous accounts by Mr. Godwin-Austen, Mr. Vivian, and the Rev. Mr. McEnery, that worked flints occurred in Kent's Hole, with remains of extinct species, was rejected as too improbable for publication.

at various remote periods, were explored in Belgium and the south of France—lake-dwellings were examined in Switzerland—refuse-heaps in Denmark—and thus a whole series of remains have been discovered, carrying back the history of mankind from the earliest historic periods to a long-distant past. The antiquity of the races thus discovered can only be generally determined by the successively earlier and earlier stages through which we can trace them. As we go back, metals soon disappear, and we find only tools and weapons of stone and of bone. The stone weapons get ruder and ruder; pottery, and then the bone implements, cease to occur; and in the earliest stage we find only chipped flints, of rude design, though still of unmistakably human workmanship. In like manner domestic animals disappear as we go backward; and, though the dog seems to have been the earliest, it is doubtful whether the makers of the ruder flint implements of the gravels possessed even this. Still more important as a measure of time are the changes of the earth's surface—of the distribution of animals—and of climate—which have occurred during the human period. At a comparatively recent epoch in the record of prehistoric times, we find that the Baltic was far salter than it is now, and produced abundance of oysters; and that Denmark was covered with pine-forests inhabited by capercailzies, such as now only occur farther north in Norway. A little earlier we find that reindeer were common even in the south of France, and still earlier this animal was accompanied by the mammoth and woolly rhinoceros, by the arctic glutton, and by huge bears and lions of extinct species. The presence of such animals implies a change of climate, and both in the caves and gravels we find proofs of a much colder climate than now prevails in Western Europe. Still more remarkable are the changes of the earth's surface which have been effected during man's occupation of it. Many extensive valleys in England and France are believed by the best observers to have been deepened at least a hundred feet; caverns now far out of the reach of any stream must for a long succession of years have had streams flowing through them, at least in times of floods—and this often implies that vast masses of solid rock have since been worn away. In Sardinia land has risen at least three hundred feet since men lived there who made pottery and probably used fishing-nets;[1] while in Kent's Cavern remains of man are found buried beneath two separate beds of stalagmite, each having a distinct texture, and each covering a deposit of cave-earth having well-marked differential characters, while each contains a distinct assemblage of extinct animals.

Such, briefly, are the results of the evidence that has been rapidly accumulating for about fifteen years as to the antiquity of man; and it has been confirmed by so many discoveries of a like nature in all parts of the globe, and especially by the comparison of the tools and

[1] Lyell's "Antiquity of Man," fourth edition, p. 115.

weapons of prehistoric man with those of modern savages, so that the use of even the rudest flint implements has become quite intelligible, that we can hardly wonder at the vast revolution effected in public opinion. Not only is the belief in man's vast and still unknown antiquity universal among men of science, but it is hardly disputed by any well-informed theologian; and the present generation of science-students must, we should think, be somewhat puzzled to understand what there was in the earliest discoveries that should have aroused such general opposition and been met with such universal incredulity.

But the question of the mere "Antiquity of Man" almost sank into insignificance at a very early period of the inquiry, in comparison with the far more momentous and more exciting problem of the development of man from some lower animal form, which the theories of Mr. Darwin and of Mr. Herbert Spencer soon showed to be inseparably bound up with it. This has been, and to some extent still is, the subject of fierce conflict; but the controversy as to the fact of such development is now almost at an end, since one of the most talented representatives of Catholic theology, and an anatomist of high standing—Prof. Mivart—fully adopts it as regards physical structure, reserving his opposition for those parts of the theory which would deduce man's whole intellectual and moral nature from the same source, and by a similar mode of development.

Never, perhaps, in the whole history of science or philosophy has so great a revolution in thought and opinion been effected as in the twelve years from 1859 to 1871, the respective dates of publication of Mr. Darwin's "Origin of Species" and "Descent of Man." Up to the commencement of this period the belief in the independent creation or origin of the species of animals and plants, and the belief in the very recent appearance of man upon the earth, were, practically, universal. Long before the end of it these two beliefs had utterly disappeared, not only in the scientific world, but almost equally so among the literary and educated classes generally. The belief in the independent origin of man held its ground somewhat longer, but the publication of Mr. Darwin's great work gave even that its death-blow, for hardly any one capable of judging of the evidence now doubts the derivative nature of man's bodily structure as a whole, although many believe that his mind and even some of his physical characteristics may be due to the action of other forces than have acted in the case of the lower animals.

We need hardly be surprised, under these circumstances, if there has been a tendency among men of science to pass from one extreme to the other, from a profession (so few years ago) of total ignorance as to the mode of origin of all living things, to a claim to almost complete knowledge of the whole progress of the universe from the first speck of living protoplasm up to the highest development of the human intellect. Yet this is really what we have seen in the last six-

teen years. Formerly difficulties were exaggerated, and it was asserted that we had not sufficient knowledge to venture on any generalizations on the subject. Now difficulties are set aside, and it is held that our theories are so well established and so far-reaching, that they explain and comprehend all Nature. It is not long ago (as I have already reminded you) since *facts* were contemptuously ignored, because they favored our now popular views; at the present day it seems to me that facts which oppose them hardly receive due consideration. And, as opposition is the best incentive to progress, and it is not well even for the best theories to have it all their own way, I propose to direct your attention to a few such facts, and to the conclusions that seem fairly deducible from them.

It is a curious circumstance that, notwithstanding the attention that has been directed to the subject in every part of the world, and the numerous excavations connected with railways and mines which have offered such facilities for geological discovery, no advance whatever has been made for a considerable number of years, in detecting the time or the mode of man's origin. The Palæolithic flint weapons first discovered in the north of France more than thirty years ago are still the oldest undisputed proofs of man's existence; and, amid the countless relics of a former world that have been brought to light, no evidence of any one of the links that must have connected man with the lower animals has yet appeared.

It is, indeed, well known that negative evidence in geology is of very slender value, and this is, no doubt, generally the case. The circumstances here are, however, peculiar; for many converging lines of evidence show that, on the theory of development by the same laws which have determined the development of the lower animals, man must be immensely older than any traces of him yet discovered. As this is a point of great interest, we must devote a few moments to its consideration:

1. The most important difference between man and such of the lower animals as most nearly approach him is undoubtedly in the bulk and development of his brain, as indicated by the form and capacity of the cranium. We should therefore anticipate that these earliest races, who were contemporary with the extinct animals and used rude stone weapons, would show a marked deficiency in this respect. Yet the oldest known crania—those of the Engis and Cro-Magnon caves—show no marks of degradation. The former does not present so low a type as that of most existing savages, but is—to use the words of Prof. Huxley—"a fair average human skull, which might have belonged to a philosopher, or might have contained the thoughtless brains of a savage." The latter are still more remarkable, being unusually large and well formed. Dr. Pruner-Bey states that they surpass the average of modern European skulls in capacity, while their symmetrical forms, without any trace of prognathism, compare

favorably not only with the foremost savage races, but with many civilized nations of modern times.

One or two other crania of much lower type, but of less antiquity than this, have been discovered; but they in no way invalidate the conclusion which so highly developed a form at so early a period implies, viz., that we have as yet made a hardly perceptible step toward the discovery of any earlier stage in the development of man.

2. This conclusion is supported and enforced by the nature of many of the works of art found even in the oldest cave-dwellings. The flints are of the old chipped type, but they are formed into a large variety of tools and weapons—such as scrapers, awls, hammers, saws, lances, etc.—implying a variety of purposes for which these were used, and a corresponding degree of mental activity and civilization. Numerous articles of bone have also been found, including well-formed needles, implying that skins were sewn together, and perhaps even textile materials woven into cloth. Still more important are the numerous carvings and drawings representing a variety of animals, including horses, reindeer, and even a mammoth, executed with considerable skill on bone, reindeer horns, and mammoth-tusks. These, taken together, indicate a state of civilization much higher than that of the lowest of our modern savages, while it is quite compatible with a considerable degree of mental advancement, and leads us to believe that the crania of Engis and Cro-Magnon are not exceptional, but fairly represent the characters of the race. If we further remember that these people lived in Europe under the unfavorable conditions of a sub-arctic climate, we shall be inclined to agree with Dr. Daniel Wilson, that it is far easier to produce evidences of deterioration than of progress in instituting a comparison between the contemporaries of the mammoth and later prehistoric races of Europe or savage nations of modern times.[1]

3. Yet another important line of evidence as to the extreme antiquity of the human type has been brought prominently forward by Prof. Mivart.[2] He shows, by careful comparison of all parts of the structure of the body, that man is related, not to any one, but almost equally to many of the existing apes—to the orang, the chimpanzee, the gorilla, and even to the gibbons—in a variety of ways; and these relations and differences are so numerous and so diverse that on the theory of evolution the ancestral form which ultimately developed into man must have diverged from the common stock whence all these various forms and their extinct allies originated. But so far back as the Miocene deposits of Europe, we find the remains of apes allied to these various forms, and especially to the gibbons, so that in all probability the special line of variation which led up to man branched off at a still earlier period. And these early forms, being the initiation of a far higher type, and having to develop by

[1] "Prehistoric Man," third edition, vol. i., p. 117. [2] "Man and Apes," pp. 171–193.

natural selection into so specialized and altogether distinct a creature as man, must have risen at a very early period into the position of a dominant race, and spread in dense waves of population over all suitable portions of the great continent—for this, on Mr. Darwin's hypothesis, is essential to rapid developmental progress through the agency of natural selection.

Under these circumstances we might certainly expect to find some relics of these earlier forms of man along with those of animals which were presumably less abundant. Negative evidence of this kind is not very weighty, but still it has *some* value. It has been suggested that as apes are mostly tropical, and anthropoid apes are now confined almost exclusively to the vicinity of the equator, we should expect the ancestral forms also to have inhabited these same localities—West Africa and the Malay Islands. But this objection is hardly valid, because existing anthropoid apes are wholly dependent on a perennial supply of easily-accessible fruits, which is only found near the equator, while not only had the south of Europe an almost tropical climate in Miocene times, but we must suppose even the earliest ancestors of man to have been terrestrial and omnivorous, since it must have taken ages of slow modification to have produced the perfectly erect form, the short arms, and the wholly non-prehensile foot, which so strongly differentiate man from the apes.

The conclusion which I think we must arrive at is, that if man has been developed from a common ancestor with all existing apes, *and by no other agencies than such as have affected their development*, then he must have existed in something approaching his present form, during the Tertiary period—and not merely existed, but predominated in numbers, wherever suitable conditions prevailed. If, then, continued researches in all parts of Europe and Asia fail to bring to light any proofs of his presence, it will be at least a presumption that he came into existence at a much later date, and by a much more rapid process of development. In that case it will be a fair argument that, just as he is in his mental and moral nature, his capacities and aspirations, so infinitely raised above the brutes, so his origin is due to distinct and higher agencies than such as have affected their development.

There is yet another line of inquiry bearing upon this subject to which I wish to call your attention. It is a somewhat curious fact that, while all modern writers admit the great antiquity of man, most of them maintain the very recent development of his intellect, and will hardly contemplate the possibility of men, equal in mental capacity to ourselves, having existed in prehistoric times. This question is generally assumed to be settled by such relics as have been preserved of the manufactures of the older races, showing a lower and lower state of the arts by the successive disappearance in early times of iron, bronze, and pottery; and by the ruder forms of the older flint

implements. The weakness of this argument has been well shown by Mr. Albert Mott in his very original but little known presidential address to the Literary and Philosophical Society of Liverpool in 1873. He maintains that "our most distant glimpses of the past are still of a world peopled as now with men both civilized and savage;" and "that we have often entirely misread the past by supposing that the outward signs of civilization must always be the same, and must be such as are found among ourselves." In support of this view he adduces a variety of striking facts and ingenious arguments, a few of which I will briefly summarize.

On one of the most remote islands of the Pacific—Easter Island—2,000 miles from South America, 2,000 from the Marquesas, and more than 1,000 from the Gambier Islands, are found hundreds of gigantic stone images, now mostly in ruins, often thirty or forty feet high, while some seem to have been much larger, the crowns on their heads cut out of a red stone, being sometimes ten feet in diameter, while even the head and neck of one are said to have been twenty feet high.[1] These once stood erect on extensive stone platforms, yet the island has only an area of about thirty square miles, or considerably less than Jersey. Now, as one of the smallest images eight feet high weighs four tons, the largest must weigh over a hundred tons if not much more; and the existence of such vast works implies a large population, abundance of food, and an established government. Yet how could these coexist in a mere speck of land wholly cut off from the rest of the world? Mr. Mott maintains that this necessarily implies the power of regular communication with larger islands or a continent, the arts of navigation, and a civilization much higher than now exists in any part of the Pacific. Very similar remains in other islands scattered widely over the Pacific add weight to this argument.

The next example is that of the ancient mounds and earthworks of the North American Continent, the bearing of which is even more significant. Over the greater part of the extensive Mississippi Valley four well-marked classes of these earthworks occur. Some are camps, or works of defense, situated on bluffs, promontories, or isolated hills; others are vast inclosures in the plains and lowlands, often of geometric forms, and having attached to them roadways or avenues often miles in length; a third are mounds corresponding to our tumuli, often seventy to ninety feet high, and some of them covering acres of ground; while a fourth group consist of representations of various animals modeled in relief on a gigantic scale, and occurring chiefly in an area somewhat to the northwest of the other classes, in the plains of Wisconsin.

The first class—the camps or fortified inclosures—resemble in general features the ancient camps of our own islands, but far surpass them in extent. Fort Hill, in Ohio, is surrounded by a wall and ditch

[1] Journal of the Royal Geographical Society, 1870, pp. 177, 178.

a mile and a half in length, part of the way cut through solid rock. Artificial reservoirs for water were made within it, while at one extremity, on a more elevated point, a keep is constructed with its separate defenses and water-reservoirs. Another, called Clark's Work, in the Scioto Valley, which seems to have been a fortified town, incloses an area of one hundred and twenty-seven acres, the embankments measuring three miles in length, and containing not less than three million cubic feet of earth. This area incloses numerous sacrificial mounds and symmetrical earthworks in which many interesting relics and works of art have been found.

The second class—the sacred inclosures—may be compared for extent and arrangement with Avebury or Carnak—but are in some respects even more remarkable. One of these, at Newark, Ohio, covers an area of several miles with its connected groups of circles, octagons, squares, ellipses, and avenues, on a grand scale, and formed by embankments from twenty to thirty feet in height. Other similar works occur in different parts of Ohio, and by accurate survey it is found not only that the circles are true, though some of them are one-third of a mile in diameter, but that other figures are truly square, each side being over one thousand feet long, and, what is still more important, the dimensions of some of these geometrical figures in different parts of the country, and seventy miles apart, are identical. Now, this proves the use, by the builders of these works, of some standard measures of length, while the accuracy of the squares, circles, and, in a less degree, of the octagonal figures, shows a considerable knowledge of rudimentary geometry, and some means of measuring angles. The difficulty of drawing such figures on a large scale is much greater than any one would imagine who has not tried it, and the accuracy of these is far beyond what is necessary to satisfy the eye. We must therefore impute to these people the wish to make these figures as accurate as possible, and this wish is a greater proof of habitual skill and intellectual advancement than even the ability to draw such figures. If, then, we take into account this ability and this love of geometric truth, and further consider the dense population and civil organization implied by the construction of such extensive systematic works, we must allow that these people had reached the earlier stages of a civilization of which no traces existed among the savage tribes who alone occupied the country when first visited by Europeans.

The animal mounds are of comparatively less importance for our present purpose, as they imply a somewhat lower grade of advancement; but the sepulchral and sacrificial mounds exist in vast numbers, and their partial exploration has yielded a quantity of articles and works of art which throw some further light on the peculiarities of this mysterious people. Most of these mounds contain a large concave hearth or basin of burnt clay, of perfectly symmetrical

form, on which are found deposited more or less abundant relics, all bearing traces of the action of fire. We are, therefore, only acquainted with such articles as are practically fire-proof. These consist of bone and copper implements and ornaments, disks, and tubes—pearl, shell, and silver beads, more or less injured by the fire—ornaments cut in mica, ornamental pottery, and numbers of elaborate carvings in stone, mostly forming pipes for smoking. The metallic articles are all formed by hammering, but the execution is very good; plates of mica are found cut into scrolls and circles; the pottery, of which very few remains have been found, is far superior to that of any of the Indian tribes, since Dr. Wilson is of opinion that they must have been formed on a wheel, as they are often of uniform thickness throughout (sometimes not more than one-sixth of an inch), polished and ornamented with scrolls and figures of birds and flowers in delicate relief. But the most instructive objects are the sculptured stone pipes, representing not only various easily-recognizable animals, but also human heads, so well executed that they appear to be portraits. Among the animals, not only are such native forms as the panther, bear, otter, wolf, beaver, raccoon, heron, crow, turtle, frog, rattlesnake, and many others, well represented, but also the manatee, which perhaps then ascended the Mississippi as it now does the Amazon, and the toucan, which could hardly have been obtained nearer than Mexico. The sculptured heads are especially remarkable, because they present to us the features of an intellectual and civilized people. The nose in some is perfectly straight, and neither prominent nor dilated, the mouth is small, and the lips thin, the chin and upper lip are short, contrasting with the ponderous jaw of the modern Indian, while the cheek-bones present no marked prominence. Other examples have the nose somewhat projecting at the apex in a manner quite unlike the features of any American indigenes, and, although there are some which show a much coarser face, it is very difficult to see in any of them that close resemblance to the Indian type which these sculptures have been said to exhibit. The few authentic crania from the mounds present corresponding features, being far more symmetrical and better developed in the frontal region than those of any American tribes, although somewhat resembling them in the occipital outline;[1] while one was described by its discoverer (Mr. W. Marshall Anderson) as "a beautiful skull worthy of a Greek."

The antiquity of this remarkable race may perhaps not be very great, as compared with the prehistoric man of Europe, although the opinions of some writers on the subject seem affected by that "parsimony of time" on which the late Sir Charles Lyell so often dilated. The mounds are all overgrown with dense forest, and one of the large trees was estimated to be 800 years old, while other observers consider the forest-growth to indicate an age of at least 1,000 years. But

[1] Wilson's "Prehistoric Man," third edition, vol. ii., pp. 123–130.

it is well known that it requires several generations of trees to pass away before the growth on a deserted clearing comes to correspond with that of the surrounding virgin forest, while this forest, once established, may go on growing for an unknown number of thousands of years. The 800 or 1,000 years estimate from the growth of existing vegetation is a minimum which has no bearing whatever on the actual age of these mounds, and we might almost as well attempt to determine the time of the glacial epoch from the age of the pines or oaks which now grow on the moraines.

The important thing for us, however, is, that when North America was first settled by Europeans, the Indian tribes inhabiting it had no knowledge or tradition of any preceding race of higher civilization than themselves. Yet we find that such a race existed; that they must have been populous, and have lived under some established government; while there are signs that they practised agriculture largely, as indeed they must have done to have supported a population capable of executing such gigantic works in such vast profusion—for it is stated that the mounds and earthworks of various kinds in the State of Ohio alone amount to between eleven and twelve thousand. In their habits, customs, religion, and arts, they differed strikingly from all the Indian tribes; while their love of art and geometric forms and their capacity for executing the latter upon so gigantic a scale render it probable that they were a really civilized people, although the form their civilization took may have been very different from that of later people subject to very different influences, and the inheritors of a longer series of ancestral civilizations. We have here, at all events, a striking example of the transition, over an extensive country, from comparative civilization to comparative barbarism, the former having left no tradition, and hardly any trace of influence on the latter.

As Mr. Mott well remarks: "Nothing can be more striking than the fact that Easter Island and North America both give the same testimony as to the origin of the savage life found in them, although in all circumstances and surroundings the two cases are so different. If no stone monuments had been constructed in Easter Island, or mounds, containing a few relics saved from fire, in the United States, we might never have suspected the existence of these ancient peoples." He argues, therefore, that it is very easy for the records of an ancient nation's life entirely to perish, or to be hidden from observation. Even the arts of Nineveh and Babylon were unknown only a generation ago, and we have only just discovered the facts about the mound-builders of North America.

But other parts of the American Continent exhibit parallel phenomena. Recent investigations show that in Mexico, Central America, and Peru, the existing race of Indians has been preceded by a distinct and more civilized race. This is proved by the sculptures of the ruined cities of Central America, by the more ancient *terra-Cottas*

and paintings of Mexico, and by the oldest portrait-pottery of Peru. All alike show markedly non-Indian features, while they often closely resemble modern European types. Ancient crania, too, have been found in all these countries, presenting very different characters from those of any of the modern indigenous races of America.[1]

There is one other striking example of a higher being succeeded by a lower degree of knowledge, which is in danger of being forgotten because it has been made the foundation of theories which seem wild and fantastic, and are probably in great part erroneous. I allude to the Great Pyramid of Egypt, whose form, dimensions, structure, and uses, have recently been the subject of elaborate works by Prof. Piazzi Smyth. Now, the admitted facts about this pyramid are so interesting and so apposite to the subject we are considering, that I beg to recall them to your attention. Most of you are aware that this pyramid has been carefully explored and measured by successive Egyptologists, and that the dimensions have lately become capable of more accurate determination, owing to the discovery of some of the original casing-stones and the clearing away of the earth from the corners of the foundation, showing the sockets in which the corner-stones fitted. Prof. Smyth devoted many months of work with the best instruments in order to fix the dimensions and angles of all accessible parts of the structure; and he has carefully determined these by a comparison of his own and all previous measures, the best of which agree pretty closely with each other. The results arrived at are:

1. That the pyramid is truly square, the sides being equal and the angles right angles.

2. That the four sockets on which the first four stones of the corners rested are truly on the same level.

3. That the directions of the sides are accurately to the four cardinal points.

4. That the vertical height of the pyramid bears the same proportion to its circumference at the base as the radius of a circle does to its circumference.

Now all these measures, angles, and levels, are accurate, not as an ordinary surveyor or builder could make them, but to such a degree as requires the very best modern instruments and all the refinements of geodetical science to discover any error at all. In addition to this we have the wonderful perfection of the workmanship in the interior of the pyramid, the passages and chambers being lined with huge blocks of stones fitted with the utmost accuracy, while every part of the building exhibits the highest structural science.

In all these respects this largest pyramid surpasses every other in Egypt. Yet it is universally admitted to be the oldest, and also the oldest historical building in the world.

[1] Wilson's "Prehistoric Man," third edition, vol. ii., pp. 125, 144.

Now these admitted facts about the Great Pyramid are surely remarkable, and worthy of the deepest consideration. They are facts which, in the pregnant words of the late Sir John Herschel, "according to received theories ought not to happen," and which, he tells us, should therefore be kept ever present to our minds, since "they belong to the class of facts which serve as the clew to new discoveries." According to modern theories, the higher civilization is ever a growth and an outcome from a preceding lower state; and it is inferred that this progress is visible to us throughout all history and in all the material records of human intellect. But here we have a building which marks the very dawn of history—which is the oldest authentic monument of man's genius and skill, and which, instead of being far inferior, is very much superior to all which followed it. Great men are the products of their age and country, and the designer and constructors of this wonderful monument could never have arisen among an unintellectual and half-barbarous people. So perfect a work implies many preceding less perfect works which have disappeared. It marks the culminating point of an ancient civilization, of the early stages of which we have no record whatever.

The three cases to which I have now adverted (and there are many others) seem to require for their satisfactory interpretation a somewhat different view of human progress from that which is now generally accepted. Taken in connection with the great intellectual power of the ancient Greeks—which Mr. Galton believes to have been far above that of the average of any modern nation—and the elevation, at once intellectual and moral, displayed in the writings of Confucius, Zoroaster, and the Vedas, they point to the conclusion that, while in material progress there has been a tolerably steady advance, man's intellectual and moral development reached almost its highest level in a very remote past. The lower, the more animal, but often the more energetic types, have, however, always been far the more numerous; hence such established societies as have here and there arisen under the guidance of higher minds have always been liable to be swept away by the incursions of barbarians. Thus, in almost every part of the globe there may have been a long succession of partial civilization, each in turn succeeded by a period of barbarism; and this view seems supported by the occurrence of degraded types of skull along with such "as might have belonged to a philosopher"—at a time when the mammoth and the reindeer inhabited Southern France.

Nor need we fear that there is not time enough for the rise and decay of so many successive civilizations as this view would imply; for the opinion is now gaining ground among geologists that palæolithic man was really preglacial, and that the great gap—marked alike by a change of physical conditions, and of animal life—which in Europe always separates him from his neolithic successor, was caused by the coming on and passing away of the great Ice age.

If the views now advanced are correct, many, perhaps most, of our existing savages are the successors of higher races; and their arts, often showing a wonderful similarity in distant continents, may have been derived from a common source among more civilized peoples.

I must now conclude this very imperfect sketch of a few of the offshoots from the great tree of biological study. It will, perhaps, be thought by some that my remarks have tended to the depreciation of our science, by hinting at imperfections in our knowledge and errors in our theories, where more enthusiastic students see nothing but established truths. But I trust that I may have conveyed to many of my hearers a different impression. I have endeavored to show that even in what are usually considered the more trivial and superficial characters presented by natural objects, a whole field of new inquiry is opened up to us by the study of distribution and local conditions. And as regards man, I have endeavored to fix your attention on a class of facts which indicate that the course of his development has been far less direct and simple than has hitherto been supposed; and that, instead of resembling a single tide with its advancing and receding ripples, it must rather be compared to the progress from neap to spring tides, both the rise and the depression being comparatively greater as the waters of true civilization slowly advance toward the highest level they can reach.

And if we are thus led to believe that our present knowledge of Nature is somewhat less complete than we have been accustomed to consider it, this is only what we might expect; for, however great may have been the intellectual triumphs of the nineteenth century, we can hardly think so highly of its achievements as to imagine that, in somewhat less than twenty years, we have passed from complete ignorance to almost perfect knowledge on two such vast and complex subjects as the origin of species and the antiquity of man.

THE SO-CALLED "CONFLICT OF SCIENCE AND RELIGION."[1]

By Principal J. W. DAWSON,
OF MCGILL UNIVERSITY.

IT may be objected that, by the introduction of a cosmogony, the Bible exposes itself to a conflict with science, and that thereby injury results both to science and to religion. This is a grave charge, and one that evidently has had much weight with many minds, since it has been the subject of entire treatises designed to illustrate the history of this conflict or to explain its nature. The revelation of

[1] Extract from a work preparing for publication.

God's will to man for his moral guidance, if necessary at all, was necessary before the rise of natural science. Men could not, more especially, do without some knowledge of the unity of God and the unity of Nature until these great truths should be worked out by scientific induction. Perhaps they might never have been so worked out; therefore, a revealed "book of origins" has a right to precedence in this matter. Nor need it in any way come into conflict with the science subsequently to grow up. Science does not deal so much with the origin of Nature as with its method and laws; and all that is necessary on the part of a revelation to avoid conflict with it is to confine itself to the statement of phenomena and to avoid hypotheses. This is eminently the course of the Bible. In its cosmogony it shuns all embellishments and details, and contents itself with the fact of creation and a slight sketch of its order; and the sacred writers in their subsequent references to Nature are strictly phenomenal in their statements, and refer everything directly to the will of God, without any theory as to secondary causes or relations. They are thus decided and positive on the points with reference to which it behooves revelation to testify, and non-committal on the points which belong to the exclusive domain of science.

What, then, are we to say of the imaginary "conflict of science and religion" of which so much has been made? Simply, that it results largely from misapprehension and misuse of terms. True religion, which consists in practical love to God and to our fellow-men, can have no conflict with true science. They are fast allies. The Bible, considered as a revelation of spiritual truth to man for his salvation and enlightenment, can have no conflict with science. It promotes the study of Nature, rendering it honorable by giving it the dignity of an inquiry into the ways of God, and rendering it safe by separating it from all ideas of magic and necromancy. It gives a theological sanction to the ideas of the unity of Nature and of natural law. The actual conflict of science, when historically analyzed, is fourfold: 1. With the Church; 2. With theology; 3. With superstition; 4. With false or imperfect science and philosophy. Religious men have, no doubt, from time to time identified themselves with these opponents, but that is all; and much more frequently the opposition has been by unwise or bad men, more or less, it may be, professing religious objects.

Organizations styling themselves "the Church," and whose warrant from the Bible is often of the slenderest, have denounced and opposed new scientific truths, and persecuted their upholders; but they have just as often [illegible]unced the Bible itself, and religious doctrines founded on it.

Theology claims to b[illegible]lf one of the sciences, and as such it is necessarily imperfect an[illegible]gressive, and may at any time be more or less in conflict with [illegible] sciences. But theology is not religion,

and may often have very little in common either with true religion or with the Bible. When discussions arise between theology and other sciences, it is only a pity that either side should indulge in what has been termed the *odium theologicum*, but which is unfortunately not confined to divines.

Superstition, considered as the unreasonable fear of natural agencies, is a passive rather than an active opponent of science, except when it becomes affected with some cruel panic. But revelation which affirms unity, law, and a Father's hand in Nature, is the deadly foe of superstition; and, as a matter of fact, no body of people who have been readers of the Bible, and imbued with its spirit, have been found ready to molest or persecute science. Work of this sort has been done chiefly by the ignorant and superstitious votaries of systems which detest the Bible as much as they dislike science.

Perhaps the most troublesome opposition to science, or rather to the progress of science, has sprung from the tenacity with which men hold to old ideas. These, which may at one time have been the best science attainable, root themselves in the general mind, in popular literature, in learned bodies, and in educational books and institutions. They become identified with men's conceptions both of Nature and religion, and modify their interpretations of the Bible itself. It thus becomes a most difficult matter to wrench them from their hold, and their advocates are too apt to invoke in their defense political, social, and ecclesiastical powers, and to seek to support them by the authority of revelation, even when this, rightly understood, might be quite as favorable to the newer views.

All these conflicts are, however, necessary incidents in human progress, which comes only by conflict; and there is reason to believe that they would be as severe in the absence of revealed religion as in its presence, were it not that the absence of revelation seems often to produce a fixity and stagnation of thought, unfavorable to any new views, and consequently to some extent to any intellectual conflict. It has been, indeed, to the disinterment of the Bible, the Reformation of the fifteenth century, that the world owes, more than to any other cause, the rapid growth of modern science, and the freedom of discussion which now prevails. The Bible is surely to be regarded as a religious book, and a very old one. Yet, its constant appeal to the individual judgment in matters of religion exposes it quite as often as science to the attacks of ecclesiastical power, and gives to those who rely on it as a rule of faith a mental stimulus which is to this day the strongest guarantee that we possess for intellectual liberty in other matters.

ASTRONOMY IN AMERICA.

By RICHARD A. PROCTOR.

DURING my visits to America in 1873–'74 and 1875–'76, I was led from time to time to notice with interest the progress and promise of astronomical science in America. My own special purpose in visiting America on these occasions partly brought these matters to my attention. The circumstance that in a country so much more thinly peopled than Great Britain it should be possible not only to obtain audiences for lectures on such a subject as astronomy, but to obtain more and better and larger audiences by far than could be obtained during a lecture-season in England for any single scientific subject whatever, appeared to me in itself sufficiently remarkable. At a first view this might have been referred simply to the fact that the Americans are a lecture-loving people, preferring the quick and ready method of learning the more striking facts of a subject from a verbal exposition to close study and application. But I soon perceived that something more than the mere desire for superficial knowledge was in question. The number of persons making close inquiry into the subject was nearly always greater (even in proportion to the much greater audiences) than in England. That still more select section of every audience, the actual workers and observers, I also found to be correspondingly large; while again and again I met with what in England is certainly very unfrequent—cases, namely, in which persons, not engaged professionally in the study or teaching of astronomy, had privately worked so zealously and so ingeniously in astronomical research as to have effected original discoveries of considerable interest.

I do not propose, however, to enter here into an account of these experiences of my own. To do so would indeed be a welcome task to me, as enabling me in some degree to express not only my sense of the interest taken by Americans in science, but also my recognition of the unvarying kindness with which I was personally received. At Boston, New York, Philadelphia, Washington, Brooklyn, St. Louis, Cincinnati, Baltimore, Chicago, Columbus, Louisville, and Minneapolis, and, in fact, at all the cities and towns which I visited, I received a generous and kindly welcome from the community, accompanied by acts of personal kindness from individuals, which I shall always hold in grateful remembrance. But this would not be the place to attempt the task—in any case no easy one—of expressing my sense of American kindness and hospitality. My present purpose is to indicate simply the remarkable progress made by Americans in astronomical science during the last half-century.

Fifty years ago there were few telescopes and no observatories in

America. It was not greatly to be wondered at that the nation should not up to that time have given any great degree of attention to scientific matters. The proportion of the population having leisure for scientific and especially for astronomical research was but small, and the Government had matters of more vital importance than to attend to the erection of observatories. For several years the attention of Congress had been called to the necessity of a national observatory, but when President Adams, in 1825, made a special appeal to this effect, his proposal met with ridicule and disfavor.

The first action toward the initiation of astronomical research in America bears date March, 1810, when it was proposed in Congress (by Mr. William Lambert, of Virginia) that a first meridian should be established for the United States (the meridian of the Capitol at Washington being selected), in order to obviate the "confusion already existing in consequence of the assumption of different places within the United States as first meridians, on the published maps and charts" in the country. The proposition was at once acted upon. In July, 1812, we find Mr. Monroe, then Secretary of State, indicating its astronomical bearing. "In admitting," said he, "the propriety of establishing a first meridian within the United States, it follows that it ought to be done with the greatest mathematical precision. It is known that the best mode yet discovered for establishing the meridian of a place is by observations of the heavenly bodies; and that, to produce the greatest accuracy in the result, such observations should be often repeated, at suitable opportunities, through a series of years, by means of the best instruments. For this purpose an observatory would be of essential utility. It is only in such an institution, to be founded by the public, that all the necessary implements are likely to be collected together, that systematic observations can be made for any great length of time, and that the public can be made secure of the results of the labors of scientific men. In favor of such an institution it is sufficient to remark that every nation which has established a first meridian has also established an observatory." Mr. Lambert brought in a bill proposing the erection of such an observatory in 1813; but nothing more was done until 1815, when the memorial on which the bill of 1831 had been based was referred to a select committee. No steps were then taken, however, to carry a bill. In November, 1818, a third memorial from Mr. Lambert was presented, and referred to a select committee; but the resolution asked for was not finally passed until March 3, 1821, when Mr. Lambert was appointed by the President "to make astronomical observations by lunar occultations of fixed stars, solar eclipses, or any approved method adapted to ascertain the longitude of the Capitol from Greenwich." In December, 1823, Mr. Lambert, in a report of his labors, gave for the longitude of the Capitol 76° 55′ 30″.54, closing his report with a strong appeal for the erection of an observatory.

Two years later, President Adams urged on Congress the establishment of a national observatory as part of a wider scheme for the advancement of knowledge. His remarks on the astronomical portion of his scheme serve well to show the position of astronomy in America half a century ago. "Connected with the establishment of a university," he says, "or separate from it, might be undertaken the erection of an astronomical observatory, with provision for the support of an astronomer to be in constant attendance on the phenomena of the heavens, and for the periodical publication of his observations. It is with no feeling of pride as an American that the remark may be made that, on the comparatively small territorial surface of Europe, there are existing more than one hundred and thirty of these lighthouses of the skies, while throughout the whole American Hemisphere there is not one. If we reflect for a moment upon the discoveries which in the last four centuries have been made in the physical constitution of the universe by means of these buildings, and of observers stationed in them, shall we doubt of their usefulness to every nation? And while scarcely a year passes over our heads without bringing some new astronomical discovery to light, which we must fain receive at second-hand from Europe, are we not cutting ourselves off from the means of returning light for light, while we have neither observatory nor observer upon our half of the globe" (!) "and the earth revolves in perpetual darkness to our unsearching eyes?"

In March, 1826, a bill "to establish an observatory in the District of Columbia" was brought before Congress and read the first and second time, but the House journals show no further trace of it. This bill was due to the recommendations of Mr. Adams, who did not relax in his efforts to secure the erection of a national observatory, though delays and disappointments occurred which might well have exhausted his energy, seeing that the dates of his renewed and for a while useless appeals were 1836, 1838, 1840, and 1842.

Passing over many circumstances in the history of these transactions, not as being without interest, but because space will not permit of their being presented here, we may proceed to the time when the actual erection of the buildings was commenced. This was in 1843, or no less than thirty-three years after the plan for an observatory was first proposed, so that fully one-half of the period which has elapsed since Lambert, of Virginia, first called his countrymen's attention to the necessity of establishing a national observatory was lost in discussions and delays. At the close of September, 1844, the new building was ready for occupancy, and the instruments were adjusted.

From 1844 to 1861 the Washington Observatory was under the superintendence of Lieutenant Maury. In September, 1846, the first volume of "Observations" was issued. Its value has been thus described by an impartial and competent judge: "Besides a fair amount of observations with the two transit instruments in the meridian and

the prime vertical, and those with the mural circle, it contained various important investigations of the errors and corrections peculiar to the instruments. Prof. Coffin's masterly discussion of the adjustments of the mural circle, and his expansion of Bessel's Refraction Tables, Walker's investigation of the latitude of the observatory, and his comparison of the standard thermometers; all of great value."

In the second volume reference was made to the discovery of Neptune, and the success of Mr. Walker, one of the assistants, in detecting, among Lalande's observations, two of Neptune, on May 8 and 10, 1795, when the planet was observed and recorded as a fixed star. "Astronomers were thus furnished with an observation of Neptune made fifty-two years before, which afforded the means of a most accurate determination of the orbit, and enabled the superintendent of the *American Nautical Almanac* to publish an ephemeris of the new planet two years in advance of all other parts of the *Almanac. The observatory was first brought into prominence by these researches.*" In October, 1849, Lieutenant (now Rear-Admiral) Davis wrote as follows to the Hon. Secretary of the Navy on this subject: "The theory of Neptune belongs, by right of precedence, to American science. In connection with its neighbor, Uranus, it constitutes an open field of astronomical research, into which the astronomers and mathematicians of the United States have been the first to enter, and to occupy distinguished places." Deprecating heartily though I do, all reference to priority or nationality in such matters as opposed to the true scientific spirit, I cannot but note how Prof. Newcomb, by his admirable researches into the theory of Uranus and Neptune, has fulfilled the hopes thus expressed nearly a quarter of a century before his labors were brought to a successful termination.

The work of the observatory, thus happily inaugurated, was prosecuted steadily till 1861, when Commander Maury left Washington to join the cause of the Confederate States. During the greater part of the war the observatory was under the charge of Captain Gilliss, who died on February 9, 1865. "It has been noted as a strange coincidence of circumstances," says Prof. Nourse, in the memoir of the observatory from which we have been quoting, "that the last morning of his life witnessed an announcement of results deduced at this observatory which had fulfilled his long-deferred hope of determining the solar parallax by simultaneous observations in Chili and in the United States. This announcement would have been peculiarly gratifying to him because these results were from the joint activity of the two observatories, founded through his exertions, 5,000 miles apart."

From 1865 to 1867 the observatory was under the superintendence of Rear-Admiral C. H. Davis, and from 1867 to the present time it has been under that of Rear-Admiral B. F. Sands. Without further considering the work accomplished at the observatory itself, which

has partaken of the general character of official astronomical research, we may consider here some of the special astronomical occasions at which the observers trained at Washington have assisted.

The total eclipse of August 7, 1869, was closely observed by parties from the observatory. Prof. Asaph Hall and Mr. J. A. Rogers proceeded to Alaska; Profs. Newcomb, Harkness, and Eastman, to Iowa; and Mr. F. W. Bardwell, to Tennessee. The observations made on this occasion were of great value and interest. The solar prominences had had their real nature determined during the eclipse of August, 1868; and the American observers were not content to repeat the observations then made, but extended the method of spectroscopic analysis to the corona. They also obtained photographs of the colored prominences. The work accomplished by the Washington observers, together with the observations made by Dr. Curtis, Mr. J. Homer Lane, of Washington City, Ind., and Mr. W. S. Gilman, Jr., of New York, and General Myer, U. S. A., form a quarto volume of 217 pages, with twelve illustrations. Of this valuable and interesting volume, 3,500 copies were printed by joint resolution of Congress.

The superintendent of the Washington Observatory was not content with this. "Believing that the experience of its officers in their observations of the eclipse of 1869 should be availed of for the further elucidation of the subjects involved in such phenomena, he addressed the Navy Department upon the subject of their employment in Europe in observing the eclipse of December, 1870; the department promptly detailed the professors who had been the observers of the previous year;" and it was doubtless through the energy thus displayed by Rear-Admiral Sands that other skillful American astronomers were enabled to cross the Atlantic for the purpose of observing that important eclipse. Unfavorable weather prevented observations of this eclipse at some of the best stations, but the American observers succeeded in establishing the accuracy of the observations made in 1869, and to them must be attributed in large part the definite demonstration of the fact, which though now admitted was then much disputed, that the corona is a solar phenomenon, and not due to the illumination of our own atmosphere only.

The part taken by the Washington Observatory in preparing for and coöperating in the observation of the transit of Venus, on December 8, 1874, is too recent to need full description in this place. I may be permitted, however, to dwell with special commendation on the manner in which American astronomers devoted themselves at that time to a task which they might fairly have thought the business of their European brethren. A transit of Venus is to occur in 1882 which will be specially American, being visible wholly or in part from every portion of the United States; and, if America had reserved her energies for that occasion, no complaint could reasonably have been

made. It was indeed the prevalent idea in Europe that that would be the course she would adopt. But, with singular generosity and scientific zeal, she not only devoted to the work of observing the earlier transit a sum largely exceeding the amount granted by any other government (and nearly twice as large as Great Britain paid), but undertook some of the most difficult portions of the work, which otherwise would have been left unprovided for. I cannot but recall with a feeling of something like personal satisfaction (though conscious that such a feeling ought to find no place in the mind of the true student of science), the gratification with which I welcomed the announcement, early in 1873, that America had undertaken to occupy positions, the importance of which I had long pointed out, but which, but a fortnight before that announcement reached Europe, had been confidently described as astronomically inferior and geographically unsuitable. The pleasure I then felt was only surpassed by that which I experienced subsequently, when news received from the various observing stations showed that at those just mentioned were achieved some of the most important successes of the occasion.

Another noble contribution made to science at Washington has been the erection of the splendid refractor 26 inches in aperture, which is now the chief equatorial of the observatory. America is fortunate in possessing in Alvan Clark the greatest living master of the art of constructing large object-glasses of good definition. He had already constructed a telescope 18 inches in aperture for the observatory at Chicago, but by the contract negotiated with him in August, 1870, by Prof. Newcomb, he was called on to achieve a far more difficult task in the construction of a telescope of 26 inches clear aperture. He has successfully accomplished this task, and the telescope has already obtained good results under Newcomb's skillful management. The most important of these is an extensive series of observations of the satellites of Uranus and Neptune, made with a view of determining the elements of their orbits and the masses of the planets round which they circle. The observation of the two Uranian satellites, Ariel and Umbriel, discovered by Lassell, and of the Neptunian satellite also discovered by him, must be regarded, on account of the extreme difficulty of observing these bodies, as a very valuable contribution to astronomy. It is pleasant to notice that Newcomb has been able most thoroughly to confirm the accuracy of Lassell's work in Malta, the mean motions of Ariel and Umbriel deduced from the Malta observations being so accurate that, says Newcomb, "they will probably suffice for the identification of those objects during several centuries." Although no systematic search has been made for new satellites of Uranus, yet enough has been done to show, "with considerable certainty," that at least the outer satellites supposed to have been seen by Sir W. Herschel "can have had no real existence" (as satellites. that is to say).

Before passing to the brief consideration of the work accomplished in some of the other American observatories, we must fully admit the justice of the remarks made by Prof. Nourse in closing his memoir relating to it. "The position now accorded to it," he says, "by the free tributes of scientific men in the Old World as well as at home, is not without honor to our country; and this notwithstanding the comparatively recent founding of the institution, and the as yet limited appropriations sustaining it. It may, therefore, justly claim a yet more generous support; and the pledge may be safely made that, if thus supported and efficiently directed, it will make returns yet more gratifying to national pride, and (which is a matter infinitely more important) advancing the highest aims of scientific research. What shall be its future records of success must remain with the support extended by the government and the fidelity of those who are intrusted with its administration."

The actual commencement of astronomical observation in America belongs to a much earlier period than that at which the Washington Observatory was erected. The first telescope used for astronomical purposes in America was set up at Yale College forty-six years ago. The first observatory, however, properly so-called, was erected at Williams College, Massachusetts, in 1836. The next was the Hudson Observatory, established in connection with the Western Reserve College, Ohio, under the charge of Prof. Loomis (now of Yale), whose works on astronomy are deservedly held in high esteem in this country as well as in America. The next in order of time came the Observatory of the High School at Philadelphia, which achieved distinction under the able management of Messrs. Walker and Kendall. The West Point Observatory was next established, and placed under the care of Prof. Bartlett. All these preceded the Washington Observatory.

Soon after the Washington Observatory had been erected, an observatory was built at Cincinnati. Its history illustrates well the way of carrying out such work in America, when the Government does not take the work in hand. The idea of erecting an important observatory in Cincinnati was first entertained by Prof. Mitchel, then Professor of Mathematics at Cincinnati College. He proposed to attempt the task without any aid from the General or State Government, by the voluntary contribution of all classes of citizens. To ascertain whether any interest could be excited in the public mind in favor of astronomy, he delivered, in the spring of 1842, a series of lectures in the hall of the Cincinnati College. With truly American ingenuity he devised a mechanical contrivance, by help of which telescopic views in the heavens were presented with a brilliancy comparable with that "displayed by powerful telescopes." These lectures were attended by large audiences, and I may add, in passing, that the interest which they excited is to this day well remembered in Cincin-

nati—no small proof of Prof. Mitchel's power as a lecturer.[1] The last lecture of the course was delivered in one of the great churches of the city (a thorough American and sensible proceeding), and at the close Prof. Mitchel submitted to the audience, consisting of more than two thousand persons, his plan for erecting a first-class observatory, and furnishing it with instruments of the highest order. He promised to devote five years of faithful effort to accomplish this task. The following course was then suggested: "The entire amount required to erect the buildings and purchase the instruments should be divided into shares of twenty-five dollars; every shareholder to be entitled to the privileges of the observatory under the management of a board of control, to be elected by the shareholders. Before any subscription should become binding, the names of three hundred subscribers should be first obtained. These three hundred should meet, organize and elect a board, who should thenceforward manage the affairs of the association." In three weeks the three hundred subscribers had been obtained, without calling any public meeting, and merely by quiet visits in which the nature of the scheme was described and explained. Then officers were elected, a directory formed, and Mitchel was sent "to visit Europe, procure instruments, examine observatories, and obtain the requisite knowledge to erect and conduct the institution, which it was now hoped would be one day reared."

When Mitchel returned, four months later, a great change had occurred in the commercial affairs of America. "Everything was depressed to the lowest point," and it was with great difficulty that a sum of $3,000 was collected and remitted to meet the first payment for the telescope of twelve inches aperture ordered of Merz. The best place for the observatory was a hill-top rising 400 feet above the level of the city. On offering to purchase this from Mr. Longworth, to whom it belonged, Prof. Mitchel was directed to select and inclose four acres, which Mr. Longworth presented to the association. On November 9, 1843, the corner-stone of the pier which was to sustain the great refracting telescope was laid by John Quincy Adams, who undertook the long (and then difficult) journey from Washington to give this proof of his interest in the cause of astronomy. When, in May, 1844, the great telescope was paid for, the funds of the association were exhausted, and the estimated cost of the building amounted to more than $7,000. In this difficulty a simple but again perfectly American plan was followed. Mechanics and others were invited to subscribe for stock in the Astronomical Society, paying their subscriptions with work. In six weeks not less than one hundred hands were at work on the hill-top and in the city. The stone of which the

[1] The same remark applies to the lectures which he subsequently delivered in New York, New Orleans, Boston, Brooklyn, and other large cities. It is almost impossible to over-estimate the service thus rendered by Prof. Mitchel to astronomy in the United States.

building was erected was quarried from the grounds of the society. The lime was burned on the hill, and every means was adopted to reduce unnecessary expenditure. Payment for stock was received in every possible article of trade; due-bills were taken, and these were converted into others which would serve in the payment of bills. In this way the building was reared, and finally covered in, without incurring any debt. But the conditions of the bond by which the lot of ground was held required the completion of the observatory in June, 1845. It was seen to be impossible to carry forward the building fast enough to secure its completion by the required time without incurring some debt. "My own private resources," proceeds Mitchel, "were used in the hope that a short time after the finishing of the observatory would be sufficient to furnish the funds to meet all engagements. The work was pushed rapidly forward. In February, 1845, the great telescope safely reached the city; and in March the building was ready for its reception." Unfortunately, just at this time, when his private means were exhausted, Prof. Mitchel's professsorship was brought, in a very summary manner, to a temporary close, in consequence of the college edifice being burned to the ground. To recruit his means without abandoning the cause of astronomy, he gave courses of lectures in the chief cities of the United States, meeting with well-deserved success.

The observatory thus erected achieved useful though not very striking results. An observatory which was erected a year or two later took so quickly the leading position, so far as the actual study of the heavenly bodies was concerned, that the progress of the Cincinnati astronomers, as indeed of most of the astronomers of the United States, received less attention than otherwise might have been the case. I refer to the observatory at Harvard (Cambridge, Massachusetts). Here one of the first equatorials ever made by Merz was erected; and by means of it W. C. Bond, and his son, George P. Bond, made highly-interesting additions to astronomical knowledge. The seventh satellite of Saturn (eighth and last in order of discovery) was detected, the dark ring rediscovered and found to be transparent; important drawings of nebulæ were made, and many other observations were effected, under the administration of the Bonds. Later, under Prof. Winlock, the Harvard Observatory has been distinguished by the excellence of the mechanical arrangements adopted there, and by M. Trouvelot's admirable drawings of solar spots and prominences of the planets Jupiter and Saturn, and of various details of lunar scenery.

In passing, I may note that at Harvard, as indeed elsewhere in America, others than professed astronomers have achieved very useful astronomical work. As Prof. Mayer, of the Stevens Institute, Hoboken, has turned his marvelous ingenuity in devising new methods of physical research to astronomical inquiries, so Prof. Cooke, of Harvard, whose special subject is chemistry, made a most important

astronomical discovery, which has since been ascribed to Janssen, who, later (though independently and by another method), effected it. Prof. Cooke made a series of observations on those bands in the solar spectrum which are due to our own atmosphere, with the object of ascertaining whether they are due to the constant constituents of the air, or to the aqueous vapor which is present in the air in variable quantity. Combining hygrometric with spectroscopic observations, he found that when the air is moist these bands are more clearly seen than when the air is dry, and by systematic observations so definitely ascertained this relation as to prove beyond all manner of doubt that the bands are due to aqueous vapor. Unfortunately, though his results were published in America, they were not published in such a way as to attract notice in Europe, and accordingly European astronomers remained ignorant of the most important fact discovered by Cooke until they had rediscovered it for themselves.

The observatory at Ann Arbor, Michigan, was erected in 1854, chiefly through the exertions of Chancellor Tappan, of the Michigan University. Dr. Brünnow, our present Astronomer Royal for Ireland, was for a long time director of this observatory. It is at present under the able control of Prof. Watson, who has added nearly a score of planetoids to the known members of the solar family.

The observatory of Dartmouth College, Hanover, New Hampshire, illustrates in a remarkable way the energy and zeal with which college-observatories are managed in America. It would be difficult to name any observatory in this country where observations of greater interest, as respects the physics of astronomy, have been made than those effected by Prof. Young with the nine-inch telescope constructed by Alvan Clark for the Dartmouth College; or than the supplementary observations made by Young with a powerful telescope conveyed to an elevated pass in the Rocky Mountains. Among his results may be specially mentioned—first, the observations of the most remarkable solar outburst yet witnessed, an outburst during which the glowing hydrogen of the prominences was driven to a height of at least 200,000 miles from the surface of the sun; and, secondly, the identification of more than 250 lines in the spectrum of the solar sierra.

And as the most interesting and characteristic observations yet made upon solar prominences are due to Prof. Young, of Dartmouth Observatory, so the most accurate and detailed drawings yet made of sun-spots are those by Prof. S. Langley, of the Alleghany Observatory, near Pittsburg.

At Chicago, a very fine telescope, eighteen inches in aperture, by Alvan Clark, has been erected; but, owing to pecuniary difficulties consequent on the great fire (followed by the commercial depression which has recently affected the United States), that observatory has suffered considerably from the want of a properly remunerated director. The Astronomical Society of Chicago has done its best to set

matters straight, but differences have arisen which have marred their efforts. In the mean time, Mr. S. W. Burnham, of Chicago, has shown admirable zeal and skill in the systematic observation of double stars, having discovered and measured more than 450 of these objects (all of a delicate and difficult nature).

But, indeed, it would be hopeless to attempt, in the short space available to me here, to give any sufficient account of the labors of American astronomers, whether attached to Government or State observatories, or working independently. Of the latter, and in my opinion not the least important class, I need cite only Drs. Rutherfurd and H. Draper, the former of whom, besides making other extremely important contributions to astronomy and physics, has produced celestial photographs admittedly better than any obtained on this side of the Atlantic; while the latter at an earlier period achieved results in celestial photography which were far superior to any obtained at that time, or for many subsequent years. The advice and assistance rendered by Dr. H. Draper to the astronomers to whom were intrusted the preparations for the recent transit, were most deservedly commemorated in a medal which the American Government honored itself by awarding to him.

The most striking feature in the contributions made by Americans to astronomy appears to me to be the skill shown in noting the essential points to be aimed at, and the fertility and readiness of resource exhibited as the work proceeds. In England, students of astronomy are too much in the habit of following conventional rules, and wasting time over unnecessary preliminaries. An American astronomer notes that some particular observation is wanted, and directs his efforts to making that observation, not considering it necessary in the first place to go over ground already repeatedly traversed by others.

I have been sometimes asked whether officialism is as rampant in America as in England in matters scientific. American scientific officials have assured me that it is, or rather (for they have not worded the matter precisely in that way) they hold that official science is properly (as they consider) paramount in their country. I was gravely assured in Washington, for instance, that the course which I had pursued in England, with reference to the suggested official schemes for observing the transit of Venus in 1874, would never have been tolerated in America, despite the fact that the course actually followed by American official science was precisely that which I had advised. It was the *principle*, so an eminent American official scientist assured me, which was in question, and no American would have been suffered to oppose as I did the course advised by the chief official astronomer. What would have happened to such an unfortunate was not clearly indicated; and I must confess that all I heard outside official scientific circles in America suggested to me that any mistake made by official science would be commented upon even more freely

in America than in England, and quite as safely. In fact, I had reason to believe that the warmth of my own welcome in America was in no small degree due to the fact that, having first proved the justice of my views, I had not been afraid to maintain them publicly against the powers that were until the proper course was adopted.

One other point remains to be noticed, the influence, namely, of religious scruples upon scientific progress and research in America. Here I must admit that I was somewhat disappointed. I expected to find America a long way in advance of England. But with some noteworthy exceptions, especially in the West, America seems to me to be behind England in this respect. It is only here and there, in England—in the Bœotian corners, so to speak, of this country—that the community opposes itself to advanced scientific ideas to the same extent as in some of the leading cities of the United States. This is partly due to two opposite influences: the Puritan element of the American population on the one hand, and the Roman Catholic element on the other. Progress, however, is being steadily made in this as in other matters. Indeed, it has been rather because America began later to bestir itself in the encouragement of free search after truth that she is at present behind England in this respect. Judging from experience in other matters, she will move rapidly now her progress has begun, and will soon occupy the position to be expected from the natural freedom and independence of the American mind. It need hardly be said that in America, as in Europe, such contest as arises from time to time between religion and science has its origin entirely from the side of religion. There as here religion (so called) attacks and denounces discoveries inconsistent with the views which the orthodox had been accustomed to advocate; and there as here, when there as no longer any choice, the orthodox quietly accept these discoveries as established facts, expressing a *naïve* astonishment that they should ever have been thought in the least degree inconsistent with received opinions.—*Advance-sheets of Popular Science Review.*

IS THE DEVELOPMENT HYPOTHESIS SUFFICIENT?

By Dr. JAMES McCOSH,
PRESIDENT OF PRINCETON COLLEGE.

THIS paper has been occasioned by the lectures of a distinguished Englishman who has visited this country; but I am to keep very much to my general subject, and not enter upon a minute criticism of Prof. Huxley. In these lectures he has abstained from entering on those exciting topics bearing on materialism and religion, which he has discussed so freely in Edinburgh and in Belfast, and in his published writings. So far the hopes of unbelievers in Scripture, and the fears

of timid Christians, and the rising rage of polemic theologians, have been disappointed. But an interest has been excited in the subject of development. In the present state of the public mind, good may arise from showing that when the doctrine of development is properly explained and understood, and kept within its legitimate sphere, there is nothing in it inconsistent with natural or revealed religion; and that the scientific truths which Prof. Huxley has expounded in these lectures do not entitle him to draw the consequences which he has done in his "Lay Sermons" and other writings.

In his first lecture the professor had light work and an easy victory. He set up two targets and shot them down. He stated and overwhelmed two hypotheses: the first, that Nature has been all along very much in the same state as it now is; and the second, the poetical account given by Milton in "Paradise Lost." It did not need an Englishman to come 3,000 miles, it did not require a man of Prof. Huxley's knowledge and dialectic skill, to demolish these fancies. I cannot remember a single man eminent in science, philosophy, or theology, defending either of these views during the last half-century. The first hypothesis was never held by religious men, though it has been defended by a few scientific men—who might have been kept from error by looking to Scripture—such as Hutton, Playfair, and Lyell in his earlier writings. The book of Genesis speaks of an order and a progression in the origination of things and of a flood covering the then peopled earth. I should not expect any one but a Don Quixote to attack Milton's exposition of a popular belief. The view given in "Paradise Lost" was not the one entertained by several of the most eminent of the Christian fathers, such as Origen, and has not been entertained by any theologian of ability and scholarship for the last age or two. It must now be forty or fifty years since Chalmers and Pye Smith and certain well-known divines of the Church of England, and President Hitchcock of Amherst, adopted the discoveries of geology and sought to reconcile them with Scripture. It is an instructive circumstance that, while Milton's account cannot stand a moment's investigation, the record in Genesis is believed by many of our highest men of science to be perfectly consistent with the latest science. I name only Prof. Dana, Prof. Guyot, and Principal Dawson, the highest authorities on this continent, and superior to Prof. Huxley, not certainly in zoölogy, but in geology. I am quite ready to give up these two hypotheses to Prof. Huxley, to hew and hack them (to use one of his own phrases) like Agag.

The second lecture is written in his best manner. There is scarcely anything in it that I am inclined to object to. He is no longer killing hypotheses which died a natural death long ago. He is arranging his materials for the defense of the theory of Evolution. He has as yet only brought forward the cases which he acknowledges are not demonstrative of the truth of evolution, but are such as must exist if

evolution be true, and which, therefore, are upon the whole strongly in favor of the doctrine of development. He makes a number of admissions. He allows that there are species which have continued unchanged, not only throughout all historical years, but all geological ages. Cuvier has shown that the ibises, dogs, and cats depicted 3,000 years ago or more on the monuments of Egypt are the same as those found in that country in the present day. The professor mentions a fish of the chalk formation named cericus, which is represented at the present day by a very closely-allied species living in the Atlantic and Pacific Oceans. He thence argues that there is no intrinsic necessity in animal forms to change and to advance, as some sciolists assume. But he labors to prove that there are cases in which varieties have become species by reason of being suited to their surroundings. He gives credit to Mr. Darwin for bringing in two great factors in the process of evolution: "One of them is a tendency to vary, the existence of which may be proved by observation in all living forms; and the other is the influence of surrounding conditions upon what I may call the parent form, and the variations which are thus evolved." He adds: "The production of variations is a matter *not at all properly understood at present*. Whether it depends on some secret machinery —if I may use the phrase—of the animal form itself, or whether it arose from the influence of conditions upon that form, is not certainly a matter for our present purpose." True, this may not be for the purpose of his lecture, but it must be cleared up before we can clear up the subject of development. The nature and laws of variations and the peculiar laws of heredity are at present shrouded in mystery. When we know more of them and of the forces at work, we shall be in a better position to determine whether varieties ever do become distinct species.

The professor acknowledges that geology does not furnish decisive evidence of one form of life passing into another. But then he claims that the geological record is not complete; that much of what is written in stone has been effaced, and that if it were complete it would show us the missing links. To equal him in candor I admit that transitional forms are ever casting up. He shows that in certain fields we have those transitions already disclosed. He dwells on the resemblances and the affinities between reptiles and birds, and refers to animals which have some of the properties of both. Thus there are birds that have teeth, and reptiles that have wings and can stand on their two hind-legs, such as the *hadrosaurus* found in New Jersey. His demonstration, as against Owen, seems to me complete here. True, there are naturalists who maintain that the teethed bird is still a bird, and the archeoptrix a reptile, a variety and not a transitional form. Still, such cases indicate a tendency on the part of the reptile to rise to the bird, and of the bird to retain properties of the reptile; and natural selection and development alone can explain this.

In his third lecture he brings forward what he regards as a demonstration. In the case of *Equus*, embracing our horse, ass, and zebra, he is able, by means of the specimens gathered in the West by Prof. Marsh, to discover the succession of horse-like forms which the hypothesis of evolution supplies. He goes back from the living horse through the like animals of the post-Tertiary in the Pliocene, middle, and earlier on to the older Eocene formation, where he finds the orohippus. "There you have four toes on the front-limb complete, three toes on the hind-limb, a complete and well-developed ulna getting forward an equality of size with the radius, a complete and well-developed fibula apparently, though it is not quite certain, and then teeth with their simple fangs. So that you are now able, thanks to these researches, to show that, so far as our present knowledge extends, the history of the horse-type is exactly and precisely that which could have been predicted from a knowledge of the principles of evolution, and the knowledge we now possess justifies us completely in the anticipation that, when the still older Eocene deposits and those which belong to the Cretaceous epoch have yielded up their remains of equine animals, we shall find first an equine creature with four toes in front and a rudiment of the thumb, then probably a rudiment of the fifth behind, and so, by gradual steps, until we come to that five-toed animal in which most assuredly the whole series took its origin. That is what I mean, ladies and gentlemen, by demonstrative evidence of evolution."

Suppose that we admit all that the lecturer claims on this subject: what then? Have we thereby set aside any doctrine of philosophy or religion? The Christian, even the Christian theologian, may say wisely: "Let naturalists dispute as they may about the derivation of plants and of the lower animals; their hypotheses, arguments, and conclusions, do not interfere with our belief that God is to be seen everywhere in his works and rules over all." It appears to me that the whole doctrine of vegetable and animal species needs to be reviewed and readjusted—and religion need not fear the result. I have been convinced of this ever since I learned, when I was ardently studying botany, that the number of species of plants had risen to two millions! I was sure that all these are works of God; but I was not sure that each was a special creation.

When a new truth is discovered, especially when it is a reaction against an old theory, it is apt to bulk so largely in the view of those who hold it that they carry it to extreme lengths, and it requires time and discussion to confine it to its own place. Thus, in old time, Thales perceiving how much water could do, and Anaximenes how much air could accomplish, and Pythagoras how much numbers and forms could account for, hastened to the conclusion that the whole operations of Nature could be derived from them and explained by them. I am old enough to remember that the brilliant discoveries of

Sir Humphry Davy led wandering lecturers and all sorts of sciolists to affirm that they could explain all things, matter and mind itself, by electricity. So, in these days, development, having furnished a key to open so many of the secrets of Nature, has led some to imagine that it can solve all the mysteries of the universe. Some of us may be inclined to admit, and to use for scientific purposes, the doctrine of development, and yet be prepared to deny that it can explain everything. The fact is, it overlooks a great many more things than it notices. There are signs of a reaction among scientific men against its extreme positions; and it is the work of the age now present to show how much development can do, and how much it cannot do. Even Darwin is obliged to call in a few germs created by God, and a pangenesis in order to account for development. Herbert Spencer acknowledges a great Unknown behind visible phenomena. Huxley recommends a worship chiefly "of the silent sort." Religion comes to them and says, "Whom, therefore, ye ignorantly worship him declare I unto you."

In the common apprehension of those who hold the development hypothesis, all that is necessary to account for the world in its present state is to suppose that millions of years ago there appeared—no one can tell how—a nebulous mass with an inconceivably high temperature, but losing its heat and ready to condense; that in the long lapse of time it took the shape of planets, satellites, and sun; and that on one of these planets—that on which we dwell—it formed into plants, animals, and finally man, all by its own power, according to natural law, or, rather, the necessity of things, without it being necessary to call in a God or a guiding providence, or to suppose that there has been a plan in a designing mind. All the defenders of the theory do not state this in express words, but it is the impression left by their expositions, though some of them, such as Herbert Spencer and Tyndall, would save themselves from the blank consequences by calling in an unknown and unknowable power beyond the visible phenomena, or by appealing to some religious feelings supposed to be deep in our nature, but which the theory would soon undermine, as being, in fact, unjustifiable and unreasonable. This is the view that I mean to meet. In examining this hypothesis there are some things which I am willing to admit as being established truths:

1. I hold the doctrine of the Conservation of Force—that is, that the sum of energy, real and potential, in the universe is always one and the same, and cannot be increased or diminished by human or mundane action. I was prepared for this doctrine when it was announced by Mayer, of Heilbronn, and by Joule, of Manchester, and expounded by Grove, of London. It seemed to me to follow from the doctrine which I had laid down in my first work—"The Method of Divine Government"—published twenty-six years ago: as to the material universe being composed of substances with properties or pow-

ers of which it cannot be deprived, and which cannot be added to nor lessened. It is this that secures the permanence of Nature, keeping it unchanged in its power or powers amid all changes of action. This energy, disappearing in one form, appears necessarily in another, and gives us what Spencer calls the "persistence of force." This ever-enduring force gives rise to development. Going out from one body, it is manifested in another. The fact is, all causation, all physical action, is evolution. The substances and powers in the agents acting as the cause are found, though in a modified form, in the effects. Proceeding on this very principle, Mayer says: "Forces are causes; accordingly, we may in relation to them make full application of the principle *causa equat effectum*," and he thus elaborated the grand scientific truth, the most important discovered in our day, that the sum of energy in the universe is always the same.

2. I admit that this power becomes more and more differentiated, that is, takes more and more diverse forms, and thus imparts an ever-increasing multiplicity and variety to the universe, and will continue to do so till the diversity breaks it up, and "the heavens shall pass away with a great noise, and the elements shall melt with fervent heat, the earth also, and the works that are therein shall be burned up." Mr. John S. Mill has been successful in showing that there is usually more than one antecedent or agent in a cause. "A man takes mercury, goes out-of-doors, and catches cold. We say, perhaps, that the cause of his taking cold was exposure to the air. It is clear, however, that his having taken mercury may have been a necessary condition of his catching cold; and though it might consist with usage to say that the cause of his attack was exposure to the air, to be accurate we ought to say that the cause was exposure to the air while under the effect of mercury." He concludes, "The real cause is the whole of these antecedents." Now, I hold that in physical Nature causes are not only usually, but invariably, of this dual or plural nature. I go a step farther, and have shown, I think, that the effects are also of the same dual or plural character. The effect, in fact, consists of the same agents or substances as the cause, but now in a new state. A picture falls from a wall and breaks a table; we say that the breaking of the table was the effect of the fall of the picture. But the true effect embraces both the picture and the table, the picture having lost its momentum, and the table being broken. It follows from all this that the new combination of agents, acting as the causes, must produce more and more varied effects, as the effects joining with other effects become causes, and ramify into branches and branchlets. The sum of the powers is one and the same, but they appear in an ever-increasing number and diversity of forms. The conservation of force thus gives a unity to Nature, while the mutual action and interaction give it its multiplicity. I remember how deeply I was interested in that paper (I read it when it appeared) of Von Baer, in which he shows

that in the germs of animals, as in the history of the production of animated Nature through long ages, there are first greater unity and simplicity, and then specific varieties more and more divergent.

3. I have never set myself, as too many religious men unwisely did, against the theory, first started, it would appear, by Kant, then elaborated by Sir William Herschel and Laplace, and perfected, I believe, by a professor in Princeton College, that the mundane system may have been formed out of original matter, evolved according to the mechanical laws with which it is endowed—first the outer planets, then the inner, and finally the sun condensed into the centre. This never appeared to me to be an irreligious doctrine, though Laplace was unhappily a man without religion.

4. Once more, I have ever stood up for a doctrine of Development. There is a development of one form of matter from another, of one force from another. There is, as every one allows, a development of the plant and animal from the parent. I see nothing irreligious in holding that the bird may have been evolved by numerous transitions from the reptile, and the living horse the old horse of the Eocene formation. An accumulation of powers, new conditions and surroundings may, it is acknowledged, produce a variety which may become hereditary. Let us suppose that they can also, in rare cases of combination, produce species: religion is not thereby undermined, either in its evidences or in its essential doctrines.

The question now arises and presses itself upon us: Can we by these acknowleged agencies explain the whole of the present state of the universe, with all its fitnesses, its harmonies, its beauty, its utility, its beneficence? The development theory, in the narrow and exclusive form which it commonly takes, overlooks vastly more than it notices. In particular, there are four grand truths kept out of sight. Without these, we cannot understand the Cosmos. When these are introduced, they bring God into his own universe, and fill it with life and love.

1. *God is present in all his Works, and acts in all their Actings.*—This is the religious doctrine. "By him all things consist." Paul, addressing the men of Athens, said: "For in him we live, and move, and have our being; as certain also of your own poets have said, For we are also his offspring." This doctrine may be so stated as to make it pantheistic. It is the one grand truth contained in pantheism, giving it all its plausibility, and making it superior to that bald theism which makes God create the world at first, and then stand by and see it go. The doctrine can be so stated as to free it from all such tendencies on the one side or the other, so as to make God distinct from all his works, and yet acting in them. This is, I believe, the philosophical doctrine. It has been held by the greatest thinkers which our world has produced, such as Descartes, Leibnitz, Berkeley,

Herschel, Faraday, and multitudes of others. It seems to be required by that deep law of causation which not only prompts us to seek for a cause for everything, but an adequate cause, to be found only in an intelligent mind. Our greatest American thinker, Jonathan Edwards (whom I can claim as my predecessor), maintains that, as an image in a mirror is kept up by a constant succession of rays of light, so Nature is sustained by a constant forth-putting of the divine power. In this view Nature is a perpetual creation. God is to be seen not only in creation at first, but in the continuance of all things. "They continue to this day according to thine ordinances." He is to be acknowledged not only in the origination of matter, but in its developments; not only in the reptile and the bird, but it may be in the steps by which the one has been derived from the other; not only in the orohippus, but in the stages by which that animal has risen into the horse so useful to man.

2. *New Powers appearing in Nature.*—Let us suppose that there was an original matter. I regard it as most in accordance with the principles of our reason to ascribe that matter to God. What properties had that matter at first? Every man of ordinary wisdom and modesty will be ready to answer, "I know not." If he does not know, he is not entitled to say that all things have proceeded from it. I suppose it will be allowed that it possessed gravitation. "This law of the inverse square," says a writer in the last number of the *Quarterly Review* (London), "is but the mathematical expression of a property which has been imposed on matter from the creation. It is no inherent quality, so far as we know. It is quite conceivable that the central law might have been different from what it is. There is no reason why the mathematical law should be what it is, except the will of the Being who imposed the law. Any other proportion would equally well be expressed mathematically and its results calculated. As an instance of what would occur if any other proportion than the inverse square were substituted as the attractive force of gravity, suppose, at distances 1, 2, 3, the attractive force had varied as 1, 2, 3, instead of the squares of those numbers. Under such a law any number of planets might revolve in the most regular and orderly manner. But under this law the weight of bodies at the earth's surface would cease to exist; nothing would fall or weigh downward. The greater action of the distant sun and planets would exactly neutralize the attractive force of the earth. A ball thrown from the hand, however gently, would immediately become a satellite of the earth, and would for the future accompany its course, revolving about it for the space of one year. All terrestrial things would float about with no principle of coherence or stability—they would obey the general law of the system, but would acknowledge no particular relation to the earth. It is obvious that such a change would be subversive of the entire structure and economy of the world."

Much the same might be said of the chemical, the electric, and magnetic properties of matter. If they were among the original powers, there is proof of design in their adaptation to one another and to the matter of the universe. If they were not, then we have traces of a new power being introduced, and for this we must look for a cause. We are not able to say how many the properties possessed by the original matter; whether they were few or many. But in either case there is evidence of contrivance in their harmonious action and results. We see that there is an end proposed in the music that comes from a violin, and this whether it is brought forth from one string, as was done by Paganini, or from four strings, as is done by the ordinary performer. So in the orderly and beneficent action of Nature there is proof of adaptation, whether we suppose the original properties to be few or to be numerous.

Though preservation is in a sense a continued creation, yet preservation differs from creation. In looking back on the history of the world, it is often difficult to tell as to a certain work to which of these two kinds of divine acts it belongs. We may not be sure, for example, as to a new form of plant or animal, whether it is a creation or simply a development according to law; and I am not sure that religion gains by our taking one side or another. We cannot, we have seen, determine for certain what were the powers of Nature that were working from the very beginning. But it is clear and sure that powers have appeared in Nature from time to time which did not operate at first nor for long ages; nay, if geology speaks truly, nor for millions of years. There may be two suppositions in regard to these powers. The one is, that they were all along in the original matter; that the star-dust had in it potentially not only gravitation and chemical affinity, but life, sensation, consciousness, intelligence, moral discernment, love. It is hard to believe that there was all this in that dull, heated, nebulous matter from which our world sprang. It is acknowledged that this mass must have existed for a long time —for hundreds of thousands, probably for millions of years—before life, and for a far longer time before intelligence, appeared. Whence did these new powers come? If they were in the original matter, how did it come that they were so long dormant, how that they at last appeared, it might be shown, at the appropriate time when surroundings were prepared for them? Science can say nothing on this subject, and may never be able to say anything. It is passing altogether beyond its province, passing from inductive proof into speculation, when it pretends to know anything one way or other. Philosophy feels itself staggered when it would solve the problem. It does say, indeed, that this new operation must have had a cause. It is one of the certain laws of intelligence, one of the universal laws of experience, that everything that begins to be must have a cause. This law of causation takes several forms; but every form will insist that these new

operations must have come from a causal power. "Ex nihilo nihil fit" is a maxim going back farther than I am able to tell. The form given it by the great atheistic poet Lucretius is:

> ". . . Nihil posse creari.
> De nihilo, neque quod, genitu est ad nihil revocari."

Persius puts it:

> ". . . Gigni
> De nihilo nihil, in nihilum nil posse reverti."

Take either of these forms, or any form, and it insists that we seek a cause of the new kind of operation. It cannot discover that there was anything in that heated, vaporous matter to produce life and sensation, when they appeared millions of years after the world had begun to be formed. I will not decide dogmatically whether the causal action was natural or supernatural. Perhaps we are here come to a place where the distinction between natural and supernatural is lost in the dim distance. The cause may have acted according to a law. But in that case I must hold it to be a divine law. Even in the supposition that it has been brought about by a conjuncture of circumstances, unknown for the indefinite period before, it must have been a providential juncture foreseen, nay, ordained by God.

Life appears ten thousand ages or more after the earth began to form. Whence this life? Prof. Huxley seems to find it in some protoplasm or gelatinous substance. Was this one of the original elements of the nebulous matter? If so, how did it come through that terribly heated temperature? If it did not exist till after the temperature had cooled, how did it come in? Prof. Huxley has been the most determined opponent in our day of the spontaneous generation of life, and is thereby left without a means of generating the life of plants and animals. Darwin feels himself obliged, in order to account for the phenomenon, to suppose that there were four or five germs created by God. Tyndall thinks that Darwin has at this point fallen into a weakness. But, meanwhile, Tyndall has no means whatever of accounting for the appearance of life. Mr. Darwin further calls in a *pangenesis*—which is just another name for the *vital force* of the older naturalists—in order to account for the generation of new animals. But he does not tell us, and evidently cannot tell us, whence this pangenesis, which cannot come from development, of which it is the source, and not the product. Herbert Spencer prefers to bring in *physiological units*.

Whence comes sensation? There was a moment when sensation pleasurable or painful was felt for the first time in the universe. Was this at the beginning? If so, one wonders how the sentient substance came through the heat, where, so far as we can judge, it must have been suffering intolerable anguish without the power of relieving itself by self-destruction.

Had this protoplasm self-consciousness? I rather think that neither Prof. Huxley nor Prof. Tyndall would say that it had. Animals from the very first have sensations, and also, at least the higher ones, ideas and very curious instincts, by which they make provision for coming evils of which they can have no conception. Finally, in the last of the unnumbered ages we have man with his intelligence, his conscience and free-will, all attested by consciousness. Will evolutionists pretend that on any rational or inductive principle they can tell how these new powers came into being and into action? When the book of Genesis tells us how these agencies did come in, and in particular how man appeared, science has and can have no facts to lead us to discredit it.

3. *There is Final Cause in Nature.*—Laplace, a great mathematician but not a great philosopher, imagined that, when we have discovered an efficient, it is not necessary to seek for a final cause. Aristotle, with a much more enlarged conception of the nature of the universe, maintained that we are to seek for both these causes—and for two others besides, the material and the formal. The fact is, that final causes presuppose efficient causes; and the efficient causes effect, by their coöperation, the final cause. We argue final cause, that is design, from the collocation of efficient causes to promote an evident end, say the ear to hear and the eye to see. The doctrine of development does not undermine or in any way interfere with the argument from design. This was asserted by Hugh Miller when the "Vestiges of Creation" was published, and has been gracefully illustrated and defended by Prof. Asa Gray in his pleasant book, "Darwiniana." When we argue that a watch has had a maker, we do not suppose it necessary that the watch should have been made by an immediate fiat of the mechanic. We so infer, because we discover agents combined to produce a particular effect, and the combination of these may have taken days or weeks of patient labor. So, the fact that the present adaptations and forms of the plant and animal may have been produced by a great number of antecedents, acting through ages, does not show that there is no design, but rather proves that there has been a bountiful end contemplated all along, and effected by a long process. Prof. Huxley, in the opening of his last lecture, has expressed his admiration—an admiration with which I thoroughly sympathize—of the structure of the horse: "The horse is in many ways a most remarkable animal, inasmuch as it presents us with an example of one of the most perfect pieces of machinery in the animal kingdom. In fact, among mammalia it cannot be said that there is any locomotive so perfectly adapted to its purpose, doing so much work with so small a quantity of fuel, as this animal, the horse." He speaks of the beauty of the animal arising "from the perfect balance of his parts and the rhythm and perfection of their action. Its locomotive apparatus is, as you are

aware, resident in its slender fore and hind legs, which are flexible and elastic levers, capable of being moved by very heavy muscles. And in order to supply the engines that work these levers—the muscles—with the force they expend, the horse is provided with a very perfect feeding apparatus and very perfect digestive apparatus." In all these things being *provided*—the phrase used by Huxley, though he has no right to use it—there is evidence of purpose, and this is not diminished, but rather increased, by the fact that the animal has been thus perfected by a long descent from an ancient progenitor. The argument of Paley and of the Bridgewater Treatises, derived from the bones and muscles of animals, and from the adjustments in every part of Nature, is as valid and convincing as ever. I believe Prof. Huxley admits this. I discover adaptation and contrivance, not only in the products but in the very process of development. Viewed in this light, development may, in the hands of a new Paley, furnish further and very striking cases of design. For, in order to the success of the process, there is often need of coördinated structure, that is, of a structure in which a number of parts are adapted to each other. My friend Mr. Joseph J. Murphy has supplied us with an instance in the case of the two nervous connections of the iris of the eye. "One of its nerves has its root in the brain, and contracts the pupil under the stimulus of light; the other has its root in the sympathetic ganglia, and opens the pupil again when the intensity of light is diminished. It is obviously impossible that the efficiency of either of these two nerves could be increased separately; they will not be improved at all unless they are improved together; and this, on Darwin's principles, can only be done by means of accidental favorable circumstances occurring in both at once. But such coincidences are so improbable that they may be left out of account as if they were impossible." I do not agree with Mr. Murphy in thinking that such an instance tells against Darwin; but I think the coincidence shows a preordained arrangement, and such coincidences are found in nearly every case of development, thus showing the need of coöperation and contrivance in the very developing process. It is to be observed that evolution, vegetable and animal, and natural selection, are not simple properties of matter like gravitation and chemical affinity. They imply the concurrence of an immense number of agents, mechanical, chemical, electric, galvanic; and Darwin adds pangenesis, and Spencer physiological units. In the concurrence and coöperation of all these to develop the plant and animal, I see proof of purpose; and in the culmination of the whole in the perfect forms of the higher animated beings, I discover a guiding intelligence which designed the end from the beginning.

4. *There are Typical Forms in Nature.*—It is now twenty years since, in conjunction with Dr. Dickie, I wrote "Typical Forms and Special Ends in Creation," in which I showed that there was not

only final cause, but a designed general order in Nature. When I composed that work I was filled with admiration of the discoveries made by Goethe and Oken, by Owen and Agassiz, as to the beautiful "forms" in Nature. Some may think that the more recent doctrine of development has made that treatise obsolete. I admit that these late discoveries might require me in some places to change my mode of expression; and the time has scarcely arrived for rewriting that book, and will not arrive till Darwin's doctrine and Owen's doctrine are more thoroughly adjusted. But, meanwhile, the argument is as valid as it ever was, and proves that there is a designed order and beauty in Nature, the design being not less evident because the order and beauty have been brought about by a process of development. This has been shown fully and satisfactorily by St. George Mivart in a recent article in the *Contemporary Review*, entitled "Likenesses or Philosophical Anatomy," in which he writes in the same way as I did of homologies, and shows that many of these cannot be explained by development or by a descent from a common parentage. He shows that "there are likenesses between different animals and different parts of the same animal which a theory of common descent cannot explain." He specifies instances of lateral, vertical, and serial homology, such as the vertebræ which make up the backbone, all similar, and the likeness between "the thigh, leg, and foot, of the lower limb, evidently more or less repeating the upper arm, arm, and hand, of the upper limb." I am inclined to argue that there is evidence of design in homologies which may have been produced by descent, as when we see the pectoral limb of the horse, the whale, and the bird—whether fore-leg, paddle, or wing—formed on one type, though turned to very different uses. All that Owen and Agassiz have said about the anticipations and the prophecies in Nature may be acknowledged as true, even by those who hold that they have been produced by development. I do believe that these old horse-like forms were preparations for the horse now living. The efficient cause may have been development, but the formal cause (to use Aristotle's phrase) is the perfected animal. We cannot allow this evolution doctrine to shear Nature of its grandeurs, nor, we may add, morality of its binding obligations or the universe of its God. Mr. Mivart concludes: "The teaching of what we believe to be true philosophy is that the types shadowed forth to our intellects by material existences are copies of divine originals, and correspond to prototypal ideas in God."

I close this article with remarking that these views bring Nature and revelation, geology and genesis, into harmony.

The Book of God begins at the beginning—with Genesis, the generation of all things. Science does not seem to tell us of a beginning. The Bible opens, "In the beginning God created the heavens and the earth." It tells us that there were an order and a progression in the generation of our world. First, there is an original creation.

Then the earth is "without form," without the order which it subsequently assumed; and "void," that is, without inhabitant. Light appears, and an alternation of day and night. There is a separation of the lighter matter from the grosser, of the aërial expanse from the earth proper. Then a separation of the sea from the land. Life now appears, and we have grass and trees. As yet the sun and moon have not appeared as formed bodies. Now, on the fourth day, they might be seen, and become dividers of times and regulators of seasons. All this is in accordance with science, which says that the earth is older than the sun; that the earth was formed out of an original matter and that there must have been light before the sun was condensed into its present form. Animals now appear first in the waters, swarming creatures and fishes, then reptiles and birds. On the sixth day we have animals—herbivorous and carnivorous. Finally, we have man. All this is very much the same order as is disclosed in geology, and was written there in that volume three thousand years before geology made its discoveries.

But we are most concerned with what, after all, is the most important to us, and that is the creation of man. There is a twofold record, the parts not contradictory but supplementary the one of the other. Chapter ii. 7: "And the Lord God formed man of the dust of the ground, and breathed into his nostrils the breath of life, and he became a living soul." This is expanded in a passage full of meaning: Psalm cxxxix. 15, "My substance was not hid from thee when I was made in secret and curiously wrought in the lowest parts of the earth," seeming to indicate a process and a preparation; "thine eyes did see my substance being yet imperfect, and in thy book all my members were written while yet there was none of them." Such is the one side, the animal side. But then we have the other side, chapter i. 26: "And God said, Let us make man in our image, after our image, after our likeness. So God created man in his own image, in the image of God created he them." All this corresponds to our experience. We feel that we have an animal part cleaving to the dust, and allying us to the brutes. But we feel also that we have a divine nature, a power of distinguishing between good and evil, a longing for something higher, a seeking after God. The Bible tells, thirdly, that this image of God has been defaced. These truths have been combined in an eloquent passage by the profound Pascal: "The greatness and the misery of man being alike conspicuous, religion, in order to be true, must necessarily teach us that he has in himself some noble principles of greatness, and at the same time some profound source of misery. . . . The philosophers never furnish men with sentiments suitable to these two states. They inculcated a notion either of absolute grandeur or of hopeless degradation, neither of which is the true condition of man. . . . So manifest is it that we were once in a state of perfection from which we are now unhappily fallen. It is astonishing

that the mystery which is farthest removed from our knowledge—I mean the transmission of original sin—should be that without which we can have no true knowledge of ourselves. It is in this abyss that the clew to our condition takes its turnings and windings, insomuch that man is more incomprehensible without this mystery than this mystery is incomprehensible to man."

SKETCH OF DR. ARNOTT.

AMONG the agencies for the diffusion of the knowledge of physics and the taste for its study in the past generation, few were more effective and successful than "The Elements of Physics," a treatise for schools, by the author whose portrait will be found in the present number of the MONTHLY. It was a work in many respects of peculiar and remarkable excellence, from the felicitous treatment of the subject, the fullness and aptness of illustration, the pleasant and attractive style, and what may be called the practicalness of the book, or the prominence it gave to the exposition of familiar phenomena. Many students of both sexes in our higher schools received a bent in the direction of scientific study from the use of this text-book, which lasted through life; and, as a new edition of the volume is about to appear, brought up to the time by judicious and able editors, there are many who would like to know something about the personal character and life of the author.

NEIL ARNOTT was born on the 15th of May, 1788, at Arbroath, in Scotland. On his father's side he was descended from a Lowland family, and his mother was the daughter of a Highland clan. His youth was passed at Dysart, near Montrose. At the age of ten he became a pupil in the Aberdeen Grammar-School, where he remained the next three years.

In consequence of having been successful at the Bursary competition at Marischal College, in 1801, he became a student there, and completed the regular course, obtaining the degree of M. A. in his seventeenth year. It was during his third year in college, under the admirable instruction of Prof. Copland, that his mind was directed to natural philosophy, which henceforth became his favorite study. He chose medicine as his profession, and went through the medical course at Aberdeen. For the purpose of completing his studies, he went to London in 1806, and became a pupil in St. George's Hospital, under Sir Everard Home. Through the influence of the latter, he was appointed surgeon in the East India Company, where he gained valuable experience for his after-work. Having settled in London in 1811, he not only obtained large success as a medical practitioner, but at the same time was collecting materials for his future work on "Physics." In 1815 he was appointed physician to the French embassy, and after-

ward to the Spanish embassy. In 1836 he became a member of the Senate in the newly-founded University of London in 1837, one of the physicians extraordinary to the queen, and in 1838 a member of the Royal Society, and subsequently of the Geological Society.

Dr. Arnott gave two courses of lectures at different times on the relation of natural philosophy to medicine. These were afterward embodied in his "Physics." In 1837 appeared his well-known "Essay on Warming and Ventilation," and, by the practical application of the theories contained in it, there resulted the stoves and ventilators which bear his name. For these and other inventions, including the water-bed, he obtained from the Royal Society the Rumford medal. On account of the assistance which he rendered to the practice of medicine, and to the general public health, he received, at the Paris Exposition in 1855, a gold medal, added to which by the emperor was the cross of the Legion of Honor. During his connection with the General Board of Health, he devoted much of his time to the subjects relating either directly or indirectly to hygiene. Not only here, but during his whole life, he had exercised and used his observing powers, so that each new experience added to his valuable stock of facts, which bore especially upon natural philosophy.

Many traits of his character made him a social favorite, and his interest in society at large has justly caused him to be ranked among the chief promoters of human welfare. All his actions were characterized in a remarkable degree by unselfishness. He used none of his inventions in his own interest, and refused to have them patented, in order that their usefulness might be more wide-spread. As Prof. Bain, one of the editors of his "Elements," remarks: "Throughout his life, and by his various inventions and publications, Dr. Neil Arnott manifested a purely philanthropic desire to extend to others the benefits of that knowledge which, from his boyhood upward, he had acquired by long and patient observation. His earnest wish was to make the path of learning easy to all. We have now before us a copy of 'The Elements of Physics' as it first appeared in 1827. Within five years of its publication, five large editions of the work were called for, and, although not then complete, it was translated into several foreign languages. It is not too much to say of this and his other works that the learned and the unlearned, the student and the philosopher, have equally benefited by his labors." In addition to his general benevolence referred to above, he strove to promote the advancement of physical science by endowing scholarships in the universities and public schools. In 1869 he gave $10,000 to the University of London, and $5,000 each to the universities of Aberdeen, Edinburgh, Glasgow, and St. Andrews. Not having accomplished a design expressed by him of leaving $5,000 to each of the four Scotch universities, his widow has carried out his plans since his death. He died on the 2d of March, 1874.

CORRESPONDENCE.

GETTING RIGHT ON THE RECORD.

To the Editor of the Popular Science Monthly.

DEAR SIR: It has always been a matter of surprise to me that some of my contributions to botanical science should be regarded as attacks on the doctrines of Darwin, or as opposed to theories of evolution. At the conclusion of the reading of my papers it is often a subject of argument on which side I stand. So great is this nervousness, that at Buffalo, because I showed that the ova-pollen of a yucca-flower was as potent as any that could be brought from another flower by an insect, I had to endure a sharp lecture from Prof. Riley, and even Prof. Morse could only help me with the audience by remarking, "We all know that Mr. Meehan is a Darwinian and an evolutionist, but must say that he has an odd way of putting it." That my good friend does not regard me as much of either is, however, clear, from his making no reference to any of my labors in his "History of Evolution."

For my own part I have not cared to be classed nominally with any party in science, but to let the facts I record speak for themselves. My ambition has been to be considered a worker in the field of original observation and research, and, if I know myself, am indifferent whether the facts help my own or any other person's beliefs or theories. Still, even an observer must have some idea of the bearing of what he sees on evolution and Darwinism, if he think at all about these things. I have thought it would do no harm if for once I entered the speculative field and put my own interpretation on the facts as I have recorded them.

Instead of opposing evolution, I think my Hartford paper was a contribution to its cause. I not only showed that in plants there is an evolution of form by slow and gradual modifications through long series of years, but also that evolution is often by sudden leaps, and that these sudden entrances were just as permanent, when the agents in natural selection favored, as any new form gradually evolved could be. I also showed the probability of whole districts changing by the operation of some inherent law, which would make the doctrine of evolution possible to those who can hardly believe every individual in a species came from one primordial form, one exact mathematical centre. Of course, so wide a generalization could not, ought not, to rest on so small a number of facts; but surely any one can see that if there be, and have been through all ages, change by sudden introductions as well as by slow modifications, there is no use in hunting in all cases for "missing links" that never existed; and I have found a plank on which Agassiz and his friends might have stood with Darwin; and I could render no better service to evolutionary views.

So in reference to cross-fertilization by insect agency, I regard myself as saving Darwinians from themselves. By cutting out a rotten branch the tree is made healthier, and the possibility of a fall prevented to those who might crawl out on it. To my mind, there is nothing more opposed to the idea of natural selection than the modern doctrines in relation to insects and fertilization. Supposing that, in accordance with the inherent tendency to variation, a new form—a slight change—occurs that renders the plant better fitted to engage in the "struggle for life" than its parent, and that it is unable to make use of its own pollen, but must have pollen by insect agency from some other flower. The advantage it has gained is at once lost, as the crossed progeny of course is brought back to near its grandparent, and these again crossed with the foreign pollen are again reduced, till in the course of a few generations the variety is near enough to be the same. The effect of continual adding of water to milk is well known. In the supposed case of our plant, it becomes "watered stock" with a vengeance. If the new form could have the power of reproducing itself exactly, and thus continue to fix a habit, as we can un-

derstand it might do in using its own pollen, we can see how "natural selection" could use "variation" to advantage. The insect only interferes with the law.

There are some few plants which never seem to fertilize except by insect or other aid. In a large number of these cases their own pollen is just as good as foreign pollen. In a few instances foreign pollen alone seems to be potent. Why must we believe, in this latter case, that it is because their own pollen is designed to be inferior, in order that foreign pollen may be brought to it? There may be many other reasons. At any rate, the creed presented to us is inconsistent with a full idea of natural selection. The survival of the fittest will be most assured by an abundance of resources. The little chickweed which flowers and seeds with the thermometer at 35°, and the common erophila at 40°, are much "fitter" to fight their way through the world in the wonderful way they do than if they waited for the spring insect to bring them foreign pollen. We can readily understand that if a flower is diseased, the pollen of that flower acting on itself would produce diseased offspring. Foreign pollen would bring back the health. With the millions of healthy flowers reproducing, the one flower diseased seems but trifling; but even so the insects can carry bad pollen to good flowers, as well as bring good pollen to diseased ones. Only that I have heard the argument from the highest in scientific standing, it would seem too puerile to mention here.

Without going further into detail, I may say that, as a matter of opinion, the observations I have placed on record aid evolutionary views in some of their weakest points, while I am really saving the doctrines of the survival of the fittest and of natural selection from injuries dealt out to them in the house of their friends.

THOMAS MEEHAN.

GERMANTOWN, PA., *September* 28, 1876.

EDITOR'S TABLE.

PROFESSOR HUXLEY'S LECTURES.

PROF. HUXLEY arrived in this country tired out from prolonged overwork, and greatly needing rest. He did not wish to speak in public, but could not escape it. He went to Nashville to visit a sister whom he had not seen in thirty years, and, being strongly urged to make a public address there, he reluctantly consented, and spoke to a large concourse on an excessively hot day. The effort prostrated him, and his voice was so strained that he did not recover his usual vocal power while he remained with us. He had not expected to make a formal public discourse at Baltimore, and therefore had to prepare one while here. His vacation thus turned out to be anything but a season of repose and recuperation, and he gave his lectures in New York under the triple disadvantage of not being up to his usual vigor, of a serious impairment of voice, and of having to prepare them as he went along—for the plan of the discussion was new, and American materials had to be worked up for its purpose. These difficulties became serious in dealing with the crowded audiences which attended his lectures, many of whom heard him but imperfectly.

His lectures were, however, well received by those who heard them, and quite as well received by the press as we had any reason to expect. That objections of all sorts should be raised was inevitable; for the doctrine of Evolution, which he advocated, is too recent, too comprehensive, too scientific, and encounters too many prejudices, to be generally or readily accepted merely because it is proved. Only a very small portion of human opinion is the product of reason. Some thought his treatment of the subject too elementary, and some thought it too restricted and inadequate, but nobody denied that it was clear, forcible, and logical. We must add that, in most cases, the pulpit has

treated Prof. Huxley with courtesy, though it could be wished that the clergy would inform themselves a little more thoroughly upon the subject before answering him with such perfunctory promptness.

In one thing both the professors, auditors, and the public generally, have been seriously disappointed. They have been led to regard Huxley as a man of pugnacious temper, a kind of controversial bully, who is only happy when in a fight. And so they expected to see some brilliant aggressive work, and that he would "polish off" his adversaries in the most approved and exciting style of polemical pugilism. But Prof. Huxley indulged in nothing of the kind, and so it was murmured round that the lectures were disappointing, and not at all up to what was expected from him. That is, the man himself, when observed, and heard, and known, contradicted the preconceived theory of the man. And here is the proper place to say that this current theory of Prof. Huxley's character is quite erroneous. He has been a good deal in controversy, no doubt, and has often hit hard; but it is a total mistake to suppose that he has ever sought or provoked strife because of combative propensities. His dominant tastes and inclinations are all, on the contrary, for quiet scientific inquiry. Controversy has, however, been thrust upon him. Standing prominently as the exponent of a doctrine that has been regarded with horror for the last twenty years by all classes, high as well as low, he has been misrepresented, and badgered, and vilified, with a recklessness that would have aroused vigorous resistance and sharp counter-strokes in any man of spirit.

In his opening lecture Prof. Huxley showed first that Nature, or the universe, has not always been what it is now. To minds that seek for causes it therefore presents the problem, How did it come to be what it is now? The theoretical solution of this problem that has prevailed in the past and is still widely accepted is, that it was called into existence a few thousand years ago in much the condition that we now know it. This is the Mosaic theory, in its old and popular interpretation. But as the Mosaic records have been reinterpreted in recent times, and as the question whether or not the doctrine is taught there is hotly disputed among those who defer to Mosaic authority, Prof. Huxley did not assume to settle the question, and wisely let the Mosaic account alone. Some newspapers were indignant at this, and charged him with cowardice and evasion for not pitching into Moses. But that was not his business, and if he had done so he would have been open to the charge of going out of his way to drag in a foreign question, and make an assault upon the Christian religion—there is no pleasing everybody. But, while keeping clear of the Scriptures, he still had to deal with the doctrine which has been universally believed for centuries to be grounded in Scripture authority, and so he took it as vividly and concretely described by a classic Christian poet more than two centuries ago. He called it the "Miltonic hypothesis," and read a graphic passage from "Paradise Lost" describing the way the animal world came into existence. Herbert Spencer has been soundly belabored by various critics for calling this view the "carpenter theory" of creation, but the great Christian poet certainly lends his authority to this interpretation of the case. He describes the creative work with great literalness as a mechanical operation, in the following lines:

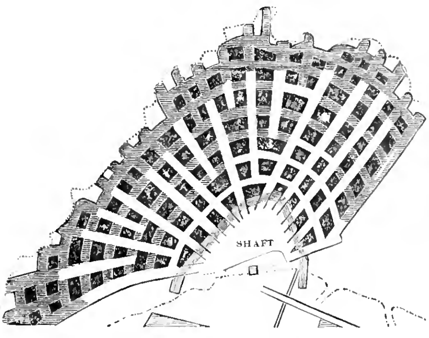
"... . In his hand
He took the golden compasses, prepared
In God's eternal store, to circumscribe
This universe, and all created things:
One foot he centred, and the other turned
Round through the vast profundity obscure;
And said, 'Thus far extend, thus far thy bounds,
This be thy just circumference O world.'"

But further comment is unnecessary, as the reader will find the full lecture in our pages.

THE HELL-GATE EXPLOSION.

The series of operations which resulted in the blowing up of the great rocky reef at Hallett's Point on Sunday, September 24th, must be regarded as the most brilliant piece of scientific engineering that has yet been accomplished. General Newton formed his plans, and entered upon the work in July, 1869. For over seven years he has been preparing for a grand experiment to occupy but a few seconds, and so accurately did he calculate, and so complete was his command of the irresistible forces to be called into action, that the experiment proved completely successful, and affords an impressive illustration of the prophetic power that is conferred by a knowledge of the elements and forces of Nature. It was the physicists and chemists who long ago worked quietly and obscurely in their laboratories, with little reference to practical ends, and animated only by the desire to acquaint themselves with the laws of the natural world, that paved the way for the great engineer to do this important service for the interests of New York and the commerce of the world.

The reef at Hallett's Point, which has formed such a dangerous obstruction in the Hell-Gate channel as greatly to hinder navigation through Long Island Sound, was of an irregular crescent shape (as shown in the figure), some



700 feet long, and extending out 300 feet into the channel, with an area of about three acres. The rock is a tough, hornblende gneiss, with veins of pure quartz, and lies in strata of various degrees of inclination. The plan of operations was to build a coffer-dam on the rock near the shore to bar out the water, to sink a shaft to the requisite depth, to honey-comb the whole rocky mass by excavation, and then to blow up the shell by charges of dynamite in the roof and supporting columns, to be fired by the agency of galvanic batteries. The shaft was sunk to a depth of 33 feet below the line of low water, and ten tunnels were then opened to distances varying from 31 to 126 feet. The cubic contents of the rocky mass, above the depth of 26 feet, at mean low water, amounted to 51,000 yards. The tunnels radiating from the shaft varied from 7 to 22 feet in height, and from 9 to 12 feet in width, and, as they advanced, the height rapidly decreased, owing to the downward slope of the surface of the reef. As the main tunnels diverged from each other, subsidiary tunnels were introduced, and a system of transverse galleries was excavated (as shown in the figure), and which left 172 supporting pillars of variable dimensions. The total length of tunnels was 4,857 feet, and the length of galleries 2,568 feet, making the entire length of passage excavated 7,425 feet. The excavations being completed, so that the roof of rock above was reduced to a thickness of from 8 to 16 feet, the preparation for the explosion began by drilling the rock for the charges. The whole number of blast-holes drilled into the roof and piers was 4,427, varying from 7 to 10 feet in depth, and from 2 to 3 inches in diameter. Each one of these holes was charged with three kinds of explosives, all compounds of nitro-glycerine, viz., dynamite, rendrock, and vulcan-powder, in separate cartridges or canisters. Fifty thousand pounds of these explosives were buried in the apertures. Ninety-six galvanic batteries, of ten cells each, were employed to ignite the charges. The firing-point was 650

yards from the shaft, and the amount of leading and connecting wire used to bring all the charges into relation with the batteries was 220,000 feet. The charges in the different holes of the same pier were connected so as to explode simultaneously, but a fuse composed of a quick explosive was used to connect the system of charges in each pier with those of the neighboring piers. In this way the electric spark, taking effect in a few centres, the ignition was propagated through the whole system, as the explosion of the connecting fuse would advance more rapidly than the destruction of the rock. The several thousand charges in the mine were connected in 23 groups, each with 160 fuses, and these were acted upon simultaneously by 23 groups of batteries. These were ingeniously connected in a mechanical arrangement so simple and perfect that a child could operate it, and the whole stupendous force that slumbered in the charges was actually released by the touch of a little daughter of General Newton, two years and a half old. The explosion was accompanied by no very stunning effects to eye or ear, and the demonstration was so moderate as to produce great disappointment in the multitudes who assembled to witness it. There was a succession of shocks, lasting a few seconds, with no great noise, a mass of water and *débris* of the coffer-dam thrown into the air, and the great reef was shattered and demolished. Long experience in blasting, and the close adaptation of explosive material to the work done, had enabled General Newton to graduate the amount of power to be developed to the total result; and so accurate was this adjustment that the explosives spent themselves in breaking up the reef, and no power was left to topple down the houses in the vicinity. Examinations thus far show that the great blast was most effectual, although considerable time and much labor will probably be required to clear away the broken masses of rock, and gain the full benefits aimed at by the enterprise.

DR. DRAPER'S BOOK AT ROME.

THAT extensive division of the Christian Church which has its headquarters at Rome has claimed and exercised for more than 300 years the right of deciding what books its members shall be allowed to read. This power resides in a body of cardinals, designated by the Pope, who issue an "Index" of books containing a twofold catalogue, one of which is of works absolutely prohibited, and the other of works that are prohibited only until they are expurgated, or so corrected by their authors as to be acceptable to the Church authorities. The first papal "Index" was published in 1549, by Pope Paul IV. It was made a part of the work of the Inquisition, and this body had charge of it until 1586, when a special commission—"The Congregation of the Index"—was created, and has been maintained to the present time. Among the early works prohibited by this conclave were those of Galileo, Copernicus, and Kepler; and, among those forbidden in more modern times, were Locke's "Essay on the Human Understanding," and Mill's "Political Economy." Dr. Draper's "History of the Conflict between Religion and Science" has now the honor of being added to the list of celebrated books which Catholics cannot read without rebelling against ecclesiastical authority.

This institution of the Catholic Church is itself the most conspicuous example we have of that great "conflict" which Dr. Draper has so vividly delineated in his little volume. Its rise was coincident with the general awakening of thought in modern Europe, which was manifested on the one hand in the Protestant Reformation, and, on the other, in that independent study of Nature by which the sciences have been

created. The Church took issue with this spirit of free thought, which it sought to repress by violence wherever and as long as it had the power, and which it still seeks to extinguish by the force of its claim to represent divine authority. It is still as vicegerent of God upon earth that the Pope interposes to stop the circulation of scientific books, and continues his warfare with the tendency to independent inquiry.

We cannot but remark how greatly the papal government mistakes the times, and how utterly it fails to realize the change that has taken place since the sixteenth century. The time has come when books are not to be *forbidden* but *answered*, and the policy of interdiction by the Vatican authorities is so futile that it becomes nothing short of a blunder. Dr. Draper's volume has been put under ban because it is pervading all Europe—two editions having been called for even in ultra-Catholic Spain. Publicly thus to mark a book for religious outlawry is simply to give to it a prodigious advertisement. Where before it had one reader it will now have ten. Men will get it, determined to find out for themselves in what its offense consists; and women will do as Eve did—taste simply because it is a forbidden thing. The only way to overcome the objectionable tendencies of any work is to point them out; and the only way to deal with its arguments is to refute them. To suppress such books in our time is out of the question; and if, in this special instance, there are among the highly-educated ecclesiastics in Rome none who can do this, the inference is that the book is unanswerable. We have, certainly, no complaint to make of the course adopted by the theological authorities at Rome, and must, at any rate, give them credit for consistency; but they forget that the world has changed a good deal since the Inquisition was established.

AS REGARDS BISHOP COXE.

It is a great mistake to suppose that bigotry and intolerance are altogether confined to the Vatican; we have excellent illustrations of this temper much nearer home. While the Pope at Rome is commanding the faithful not to admit Dr. Draper's book into their libraries, Bishop Coxe, the little pontiff of Western New York, is warning the good Christians of Buffalo not to let Prof. Huxley come into their houses; while both potentates put their intolerant action on the same ground of divine authorization. One would think that in the nineteenth century, in an enlightened American city, in the year of the nation's centennial, in the midst of a presidential campaign, and at a large convocation of the scientists of this and foreign countries, Buffalo Christians might have been left to their own good sense and good taste to entertain whom they pleased. Moreover, Prof. Huxley was the guest of the American Scientific Association, which was itself the guest of the city, and this should have been sufficient to protect him from insult from such a quarter. It is well that the bishop's type of Christianity does not prevail in Buffalo, as, otherwise, the obnoxious foreigner might have been left in the streets to starve.

Some of the Buffalo papers, holding the bishop's utterance in regard to Huxley to be nothing less than a public affront and a disgrace to the town, made it rather warm for him, and so he has followed up the original mandate by a defense of it in subsequent letters to his organ, "The Orbit." The faithful were admonished to withhold their hospitalities from Prof. Huxley, because he is an atheist. The bishop charges him with "scientific atheism"—whatever that may mean—and refers to his admonition to his flock for "importing atheism into their families under color of science." He also accuses Prof.

Huxley of being a "propagator of atheism." Now, though these charges are launched from the Episcopal throne of Western New York, they are nevertheless not true. Bishop Coxe says, "I bear a divine commission." Then he has a divine commission to bear false witness. His accusation is simply a baseless calumny, and in none of his communications does he offer a shadow of proof to substantiate the charge. Prof. Huxley has never avowed himself an atheist, and has never advocated the doctrine, but on the contrary he has distinctly condemned it and declared it to be an absurd doctrine. Bishop Coxe says he is "a propagator of atheism," but where is the proof? There are such people as avowed atheists, and there is a party of them in England that labors to propagate the belief. Bradlaugh is one of their chiefs, who boasted that he is the only man who ever ran for Parliament on the issue of being an atheist. Prof. Huxley has never had anything to do with this party, and is no more in sympathy with it than is Bishop Coxe. If Prof. Huxley has propagated atheism, he must have done it some time, somewhere, and somehow, and there must be evidence of it. Has the bishop any better source of information than other people? If not, then he has lent himself to a false accusation. He quotes Scripture copiously in defense of his course, and cites from St. John the following passage: "Many deceivers are entering into the world. Look to yourselves . . . receive them not into your house." But, who are the deceivers, if not those who mislead people by untruthful statements? The utmost defense that Bishop Coxe can make is, that he has heard Prof. Huxley called an atheist, or that he infers from his books that he holds atheistic opinions; but is a man to be stripped of his character, and loaded with opprobrious epithets, and are all good Christians to be invited to slam their doors in his face, because of mere idle rumors and inferential constructions of his writings, both of which are contradicted by his explicit averments? The Bishop of Western New York should migrate to Rome, where he properly belongs, at the earliest opportunity.

LITERARY NOTICES.

Talks about Labor, and concerning the Evolution of Justice between the Laborers and the Capitalists. By J. N. Larned. Pp. 150. Price, $1.50. D. Appleton & Co., 1876.

This book is the result of an able effort to analyze the present relations of capital and labor, and to point out the directions whence future improvement in those relations must come. It has not the pretensions of an exhaustive treatise; nevertheless it is a study of the whole subject, and reaches to large conclusions. It is conceded on all sides that, as between laborers and capitalists, grave problems have to be settled before their relations can be adjusted to the higher notions of justice now pressing on the minds of men. The men with capital, and those without it, but with capabilities for work, must be in constant coöperation, the terms of which are determined by complex facts. The fairness or unfairness of these terms bears closely on our social life, and is an index to the quality of our civilization. We cannot turn away from them, relying entirely for their amelioration on the operation of forces beyond human control. The social philosophy imbued with the spirit of science tells us that the institutions of social life develop only in obedience to irresistible currents of educated feeling and opinion.

Without stopping to consider this thorny question, it may safely be said that prevailing mental and moral conceptions are a factor of intense importance in determining the forms of social action, and, as they pass from lower to higher states, a corresponding improvement occurs in everything upon which they act. With equal safety we may assume that this progress in our conceptions is in no way more promoted than by that activity of mind which

seeks to comprehend facts, and their relations to ethical truths.

The author of this work, profoundly impressed with the importance of the questions he discusses, has devoted himself to that consideration of his subject which includes a careful examination of existing conditions, with an inquiry into possible changes in the direction of a more complete justice between capitalists and laborers. It is a piece of good fortune that the task has been taken up in this case by a writer free from the eccentricities or narrownesses which too often beset those who discuss social questions. The literature on the subject of capital and labor is rapidly increasing, and much of it is open to a common criticism. The range of view is either too narrow, the formulæ of political economy being accepted as final and complete; or we find ourselves at the mercy of a being, utterly unscientific in his methods, who proposes to set things right by means little better than magic. Into neither mistake has Mr. Larned fallen; for, on the one hand, he has a correct appreciation of the limits to the laws which the economists have formulated, and, on the other hand, his faith rests on means of attaining ends which the most rigid scientific investigators of society must commend. As conditions change, economic science takes note and sets about the explanation of the new facts. The science is a growing one, and to take its statements to-day as an approval of existing forms of industrial life is to misconceive its nature. As Prof. Cairnes has clearly stated the point:

> "It (economic science) belongs to the class of sciences whose work can never be completed, never, at least, so long as human beings continue to progress: for the most important portion of the data from which it reasons is human character and institutions, and everything consequently which affects that character or those institutions must create new problems for economic science."

The perception of this fact leads to an appreciation of our author's fundamental views. He disputes no generally-accepted economic conclusions, but gives due weight to factors, at present excluded, which, slowly gathering force, will raise new problems. He steps out into the broad field of social inquiry, and seeks to bring into clear view agencies which must in time affect human character, and modify the institutions of the present. In addition to this, the nature of those modifications is foreshadowed.

To show how clear and strong our author's position is in respect to social reforms, it is only necessary to glance for a moment at his conception of the evolution of justice in the department of human society with which he is concerned. After analyzing the function of capital, and defining it with rare precision as being "everything derived and accumulated from past labor which enables present labor to be employed in any such way that the beneficial results from it have to be waited for," two other facts of startling import are brought into juxtaposition. They are, first, *that every kind of labor which does not immediately produce for the man who performs it the immediate satisfaction of an immediate want is absolutely dependent upon capital;* and, second, *that this complex social state which we call civilization has left no labor to be done by any man that is not of that dependent kind.* Here is the dependence of labor upon capital brought home to us by a mere statement of facts. Pushing further the analysis of the conditions upon which capital and labor bargain together, and the reality of this dependence is intensified. We are invited to look at the man of capital and the man of work in the concrete, in order to realize the motives and necessities which to a large extent determine their relations to each other. The capitalist becomes an employer mainly to increase his means; the desire of gain is the most powerful motive shaping his conduct. As a bargainer, he therefore occupies a position of comparative independence. The empty-handed laborer is very differently situated. He must live; the physical wants of himself and family must be supplied; he bargains with inexorable needs at his back. Given these conditions, and human nature not apt to rise to high motives, and it is palpable that there is no limit to the possible oppression. No one claims that capital exercises to-day all the advantages of its superior position. The reasons that it does not are found in prevailing moral ideas which have

hold enough on society to restrain its conduct in some directions and elevate it in others. But these advantages are still, to an enormous extent, made use of in the division of the products of labor between the capitalists and the laborers, and, as a result, there is deep injustice in the industrial world. There has been some improvement in the past; the hopeful man sees reasons to believe in its continuance. Mr. Larned has a large faith: perceiving that this improvement has sprung from moral sources, from the slow working of juster ideas into juster conduct, he looks to the same sources for the higher progress of the future, and has been led to examine our institutions, to find out what readjustments are necessary.

Before we can follow an author, who has such a position to maintain, into the main body of his thesis, we are in self-defense bound to assure ourselves that he has an adequate conception of man's moral nature, and the working of moral forces. If he be defective here, his work must be unfruitful. Mr. Larned has spoken plainly and at length on the subject, and his views are so broad as to inspire a full confidence in his mental grasp and scientific culture. His discussion of this point is an excellent piece of exposition. The whole statement is clear and incisive, and there is about it that impressiveness which lodges a fact of grave import firmly in the mind. It is difficult to select any portion for quotation, owing to the logical connection between all its parts. We merely give here a conclusion that he arrives at, as it bears on what we have to say: "There is this order, as I believe, in the development of humanity: 1. Toward objective or sensuous intelligence; 2. Toward subjective or moral intelligence; 3. Toward the disciplining of the animal man to act in accord with his intelligence. The first of these will always be far in advance of the second; the second always in advance of the third; and yet the first and the second contribute steadily to the last, in which their whole divine purpose would seem to be consummated."

With this key given us, it is seen that the evolution of that justice which is ultimately to correct the most glaring iniquities in the relations of capitalists and laborers proceeds from the application of the accepted principles of morality to the facts attending those relations, and the deduction therefrom of higher rules of conduct. This means that the human mind has to pass through a period of moral enlightenment—a period marked by the extension of simple notions of right to the relationships in question. The average intellect does not move swiftly of its own accord to such a task, nor does it incline, by patient efforts of its own, to penetrate the darkness of a deep subject, for guidance to intelligent action. More courageous spirits must sift and analyze the material; must place by the side of the conclusions gathered together the teachings of the ethical system which humanity has worked out—and to time must be left the slow but inevitable adjustment of human conduct to the dictates of the higher intelligence thus spread abroad. The work before us is an attempt to do for its subject what has been hinted at as open to the investigator, adding to this a brief but suggestive inquiry into the changes in the machinery of industrial life which will insure to the laborers a larger share in the products of labor. In a word, it may be said to be the bringing together of the moral and economical aspects of the labor-question. A mere allusion to some of the various topics examined is all that our space leaves us.

The subjects first treated are of a general character, and are taken up to enable the author to elaborate the theoretic relation between capital and labor, deducible from primary principles. Under this head it is sought to roughly but fairly define the extent to which the advantages flowing from superior faculties may be legitimately exercised. Leading out of this theme is the allied one of the relative value of the faculties which contribute to production. If a fund is to be shared between the various contributors to it, Justice says, Let the principle of division be based on a comparison of the used energies and capabilities of the contributors. The products of labor are not divided on this principle now, and never will be until the millennium; but it is the ideal standard toward which we must tend. There is no justification in reason for the giant's share going to one class, as it actual-

ly does. Mr. Larned is particularly happy in his estimate of the faculties which are essential to the acquisition of wealth in the business-world. His analysis, too, discloses just grounds for raising the estimate usually put upon the faculties which produce the skillful mechanic, artisan, clerk, or other efficient laborer. The comparison of these two sets of faculties dispels the common notion that, as agents in the work of production, they are of widely different quality. That there is a difference is conceded; that capital is entitled to by far the largest share of remuneration is also conceded; the point is, that it exacts a larger share than any equitable principle of division gives to it.

This plea being made for labor, the author's hard work begins in finding a way to escape from the economical conclusions about the "wages-fund," in showing how that fund may be increased so that labor may receive a larger hire, and in shaping a practical plan for the accomplishment of the desired end. We commend this part of Mr. Larned's work for the strong thought and practical sagacity behind it. He is clear when he has hard knots to untie. The "wages-fund" in the hands of an economist has always appalled us. The limits to it are sketched as inexorably determined by conditions out of human reach, and the only relief open is the relative lessening of the numbers of those who share in it. Can any one wonder at men shrinking from the gloom of such a belief? Mr. Larned holds by another and more inspiring doctrine. His effort is to prove that the enormously increased productiveness of labor, through the operation of many causes which he enumerates, is more than sufficient to supply the fullest meed of legitimate human desires. If it is not so now, it is because of unjustifiable consumption and other wrongs. Let the consumption which grows out of the low desire to parade the possession of wealth be restrained by the heavy hand of public opinion, and let public-debt making be kept within certain defined bounds, so that this avenue of unproductive capital may be practically closed—let this much be done, and the result will be that those who command capital will be driven to devote more and more of it to renewed production. To such means does the author look for the increase of the fund out of which labor is paid. We have only indicated the drift of the argument.

The practical plan, advocated tentatively by the author, is a system of dividends to labor, the basis of which is given at some length. Other plans are subjected to criticism, and their defects pointed out. The system of some sort of a partnership between capitalists and laborers obviates many of these defects, but is not without its attendant difficulties. Mr. Larned has given cogent reasons for his preference, and we hope they will be given the consideration they deserve. His views are so opposed to everything that is visionary, and are kept in such a close relationship to the facts, that his critics will find him no mean antagonist.

We had marked for comment other points in this original and interesting book, which we have no space for. What has been said falls short of doing the author justice. Indeed, this book is so compacted, and so brimful of suggestive lines of inquiry, that no summary of it can be adequate. It is a calm presentation of a difficult subject, and the temper of its conclusions will give it weight in the solution of pending problems. It has a mission which it is bound to serve worthily. The task the author unpretentiously set himself has been well done, and to other merits must be added that of literary excellence. The matter is presented in the shape of a series of conversations, and they are conducted with a skill which provokes a sharp interest in the discussions from beginning to end. The argument is carried on logically; each proposition is separated and clearly put. Those who take up the book will lose little time in finishing it, and they will find in its pages much good and substantial thought.

Correction.—It was erroneously stated last month in the review of the "Scientific Basis of Faith" that the book "is an attempt to harmonize Scripture with science." The reading should be "it is *not* an attempt," etc., conveying just the opposite meaning.

PUBLICATIONS RECEIVED.

The Theory of Color in its Relation to Art and Art-Industry. By W. von Bezold. Pp. 300. With Colored Plates. Boston: L. Prang & Co. Price, $5.

Fifty Years of my Life. By George Thomas, Earl of Albemarle. Pp. 430. New York: H. Holt & Co. Price, $2.50.

Ivanhoe. Pp. 287. Our Mutual Friend. Pp. 350. (Condensed Classics Series.) Same publisher. Price, $1.

Elementary Biology. By Prof. Huxley and H. N. Martin. Pp. 280. New York: Macmillan. Price, $2.

A Song of America. By V. Voldo. Pp. 206. New York: Hanscom & Co.

California Notes. By C. B. Turrill. Pp. 242. San Francisco: Bosqui & Co. print. Price, $1.50.

Theory and Calculation of Continuous Bridges. By M. Merriman. Pp. 130. New York: Van Nostrand. Price, 50 cents.

Goethe's ausgewählte Prosa. Edited by J. M. Hart. Pp. 200. New York: Putnams. Price, $1.

Die aromatischen Nitroverbindungen. Von Peter Townsend Austen. Pp. 43. Also, Ueber Dinitroparadibrombenzole und deren Derivate. Pp. 3. Same author.

Proceedings of the American Chemical Society. Vol. I., No. 1. Pp. 81. New York: J. F. Trow print.

Papers on Building Associations. Pp. 29. Philadelphia: Social Science Association.

Democracy: The First Century of the National Life. By Josiah Riley. Pp. 55. San Francisco: Carmany & Co. print.

Continuous Girders and Draw-Spans. By A. J. Du Bois, C. E. Pp. 32. Philadelphia: Kildare print.

Determination of Secondary Meridians by Electric Telegraph. Pp. 29. Washington: Hydrographic-Office.

Development and the Deity. By H. Faulds. Pp. 41. Yokohama: F. R. Wetmore & Co.

Bulletin of the Nuttall Ornithological Club. September. Cambridge (Mass.): published by the Club.

Report of the Director of the Central Park Menagerie. Pp. 57. New York: The National Printing Co.

The Greenstones of New Hampshire. By G. W. Hawes. Pp. 9. From *American Journal of Science and Arts.*

Conflict between Darwinism and Spiritualism. By J. M. Peebles. Pp. 34. Boston: Colby & Rich.

Researches in Telephony. By A. Graham Bell. Pp. 10. From "Proceedings of the American Academy of Arts and Sciences."

Seventh Catalogue of New Double Stars. By S. W. Burnham. Pp. 4. From *American Journal of Science and Arts.*

Prehistoric Remains found at Cincinnati. By Robert Clarke. Pp. 34. Cincinnati, 1876.

Nature of Diphtheritic Poison. By B. Robinson, M. D. Pp. 15. New York: W. Wood & Co.

Book of the Balance of Wisdom: An Essay. By H. C. Bolton, Ph. D. Pp. 30. New York: J. F. Trow print.

Proceedings of the Davenport Academy of Natural Sciences. Vol. I. Pp. 293. With numerous Plates.

MISCELLANY.

Supplement to the Glacial Theory.—At the Buffalo meeting of the American Association Prof. W. C. Kerr, State Geologist of North Carolina, read a paper accounting for the presence and characteristics of the drift or unstratified superficial deposits of North Carolina, which cannot be attributed to glacial action or the action of water, and which has hitherto presented a somewhat puzzling problem to geologists. He considers it to be the result of land-slides, or, as he terms them, earth-glaciers, formed from the detritus of the stratified rocks of the foot-hills mixed with water—the mass throughout its whole depth, of from fifteen

to thirty feet, being penetrated by the frosts of the glacial epoch, and subject to the same laws of action as real glaciers.

The course of the fragments of different strata, as shales, quartz-veins, etc., can be traced down the slopes, showing unmistakably the mode of action; and the distribution of bowlders and of gold throughout this drift, though otherwise inexplicable, is readily accounted for by this hypothesis.

A Note on the Radiometer, by Prof. T. C. Mendenhall, of Columbus, Ohio, explained his method of illuminating this instrument for the purpose of projecting an enlarged image of the arms or fans upon a screen.

The radiometer being suspended vertically, a beam of light is reflected upward through it, and made to fall upon a mirror above, which, with the aid of a projecting lens, produces the image of the movable fans upon the screen. As the beam of light produces no motion when striking these fans edgewise, the most delicate experiments can be made, and their effects seen, without any disturbance caused by the light used in projection.

On cooling the Air of Buildings during Hot Weather, by Prof. Simon Newcomb, was a valuable paper, which was practical enough to satisfy those who demand that the value of all scientific labors shall be tried by the test of utility. The failure of the many plans which have been suggested for cooling buildings in summer has arisen from overlooking the fact that the human body is a "wet-bulb thermometer," and that the air needs not alone to be cooled, but to be brought to a condition which will allow speedy evaporation, and that, therefore, contrivances for simply cooling the air have not resulted in a degree of comfort at all commensurate with their trouble and expense. We have but to remember the discomfort of a moist, "muggy" day, even when the mercury marks a moderately low temperature, to see that the air needs not only to be cooled, but to be dried. It will not answer to dry the air by chemical absorption, as by sulphuric acid or lime, on account of the heat of the chemical union.

The only satisfactory way to remove the moisture is by condensation and deposition, and for the purpose of doing this effectually and economically Prof. Newcomb suggests an apparatus. He proposes, by passing the ordinary air of a summer day through an ice-chest, to reduce it to a point far below the dew-point—or, say, 35° Fahr. Thence it should be passed through a very large tin tube on its way to the outside air. Inclosing this cold-air tube, is to be another, still larger, through which warm air from the apartments is to be forced; the two streams passing in opposite directions, the readily conducting substance of the tubes facilitating the vigorous efforts of the hot and cold currents to reach an equilibrium, the moisture being, meantime, rapidly deposited on the large condensing surfaces of the tubes. The outlets of the tubes are to be together, and the resulting mixture would be a volume of dry air at a comparatively low temperature. If, for example, the air in passing through the ice-box was reduced to 35°, while the air admitted to the outer tubes was at 95°, the result would be a mixture of dry air at about 70°, which, if mingled in considerable volume with the ordinary air of a room on a hot summer day, would be greatly conducive to comfort. The greatest value of Prof. Newcomb's suggestion is in utilizing the cold air on its passage for the purpose of condensing moisture. As to the quantity of ice needed to cool a given space, Prof. Newcomb was not prepared to give any exact figures, although he had made some estimates. He thought, however, that, at the price of ice in Washington, the cost of cooling the Capitol would be forty or fifty dollars per day.

Some New Points regarding the Tongue of the Picus Viridis (green woodpecker) was the title of a brief paper by Dr. Joshua Lindahl, of Sweden, in which he pointed out some errors in the common descriptions of the remarkable extension of the hyoid bones over the skull, which characterizes the woodpecker family. Having occasion to dissect the head of the green woodpecker of Sweden, he observed that the elongations of the posterior cornua of the hyoids, instead of passing symmetrical-

ly over the skull and terminating at the posterior end of the bill, as usually depicted in the text-books, were both carried to the right of the median line of the skull, and extended along the right side of the upper mandible, nearly or quite to its tip. Subsequent examination of numerous specimens showed this to be an accidental variation, but characteristic of the genus. A few of the black and pied species were examined, showing the same lack of symmetry, and differing only in the horns or muscles terminating at the base of the bill. Dr. Lindahl offered no explanation of these peculiarities, but called attention to the fact that the food of the green species varied considerably from that of the others, being sought deeper in the trees, and hoped that ornithologists and entomologists would consider the points of sufficient interest to seek their explanation. In the brief discussion which followed, the *asymmetry* of position and the *extension* of the muscles to the end of the mandible were spoken of as of interest, and as being new to ornithologists. While it is always important that errors in our text-books should be pointed out and corrected, the assumption that the facts are wholly new would seem to be somewhat hasty.

In this connection it may be sufficient to point out that Huxley ("Anatomy of Vertebrated Animals") says: "The free ends (of the posterior cornua) are inserted between the ascending and maxillary processes of the *right* pre-maxilla." In the "American Cyclopædia," the point of attachment is stated to be "usually near the opening of the *right* nostril;" while Wilson, writing early in the century, describes them as follows: "The os hyoides is divided into two branches that pass, one on each side of the neck, to the hind-head, where they unite, and run up along the skull in a groove; descend into the upper mandible by the *right* side of the right nostril, and reach to within half an inch of the point of the bill, to which they are attached by another extremely elastic membrane. In some species these cartilaginous substances reach only to the top of the cranium; in others they reach to the nostril; and in one species they are wound around the bone of the right eye, which projects considerably more than the left for their accommodation."

Bartlett's Ozone-Generator.—An apparatus for the generation of ozone was exhibited to the Association by the inventor, Dr. F. W. Bartlett, of Buffalo.

The machine is divided into three parts, each having a share in the process. The base, or generator, is a glass vessel eight inches high, with a projecting rim at either end; the interior space, four and a half inches in diameter, being divided into eight compartments by projections from the inner wall, extending one and a quarter inch toward the centre. This unoccupied centre has a movable cylinder which, when in position, completes the walls of the separate cavities. In each of these a tablet of phosphorus, one by two inches, and one-eighth of an inch thick, is suspended in water by a fusible wire—the fusible wire being used so that in cases of ignition, which sometimes occurs, the phosphorus may be completely submerged and the flame extinguished. Resting upon the base is a conical cylinder, eight inches high, and with a diameter at the top of five inches, composed of double walls of wire-cloth, between which lies some porous material saturated with a strong alkaline solution. This presents an effectual bar to the passage of phosphoric acids, while it permits the free transit of the ozone. Above this eliminating-chamber is a second glass cylinder about eight inches in height, with an aperture at the top through which passes a glass rod carrying a plunger for displacing the water in the base, and by means of which the tablets of phosphorus may be raised or lowered. The space thus provided above the phosphorus is about eighteen inches, and is considered by the inventor indispensable to the full utilization of the phosphoric vapor in the production of ozone.

In its present form the machine is employed chiefly for disinfecting purposes, and performs such work not only thoroughly but very cheaply. For ozonizing the atmosphere of a house, the slow oxidation of 100 to 150 grains of phosphorus daily will suffice. It is entirely manageable and without any disagreeable odor.

Dr. Bartlett claims that ozone possesses very important curative properties, has employed it successfully in numerous cases of asthma, hay-fever, typhoid fever, scarlatina, diphtheria, puerperal fever, erysipelas, etc. He predicts that its introduction will work great changes in the medical treatment of zymotic or malarial diseases. While making due allowance for the enthusiasm of an inventor, it must be admitted that Dr. Bartlett has produced a machine which does well the work for which it was intended.

Science in the United States.—Sir William Thomson, in the presidential address to the Physical Section of the British Association, spoke as follows of the work of some of our American scientific men:

"I wish I could speak to you of the veteran Henry, generous rival of Faraday in electromagnetic discovery; of Peirce, the founder of high mathematics in America; of Bache, and of the splendid heritage he has left to America and to the world in the United States Coast Survey; of the great school of astronomers which followed—Newton, Newcomb, Watson, Young, Alvan Clark, Rutherfurd, Draper, father and son; of Commander Belknap and his great exploration of the Pacific depths by piano-forte wire with imperfect apparatus supplied from Glasgow, out of which he forced a success in his own way; and of Captain Sigsbee, who followed with like fervor and resolution, and made further improvements in the apparatus by which he has done marvels of easy, quick, and sure deep-sea sounding in his little surveying-ship Blake; and of the admirable official spirit which makes such men and such doings possible in the United States naval service. I would like to tell you, too, of my reasons for confidently expecting that American hydrography will soon supply the data from tidal observations, long ago asked of our own Government in vain by a committee of the British Association, by which the amount of the earth's elastic yielding to the distorting influence of sun and moon will be measured; and of my strong hope that the Compass Department of the American Navy will repay the debt to France, England, and Germany, so appreciatively acknowledged in their reprint of the works of Poisson, Airy, Archibald Smith, Evans, and the Liverpool Compass Committee, by giving in return a fresh marine survey of terrestrial magnetism to supply the navigator with data for correcting his compass without sights of sun or stars. I should tell you also of 'Old Prob's' weather-warnings, which cost the nation \$250,000 a year, money well spent, say the Western farmers, and not they alone; in this the whole people of the United States are agreed; and though Democrats or Republicans playing the 'economical ticket' may for half a session stop the appropriations for even the United States Coast Survey, no one would for a moment think of starving 'Old Prob;' and now that 80 per cent. of his probabilities have proved true, and General Myer has for a month back ceased to call his daily forecasts 'probabilities,' and has begun to call them 'indications,' what will the Western farmers call him this time next year?"

The French Association.—The fifth session of the French Association for the Advancement of Science was opened at Clermont-Ferrand, on the 18th of August. In the opening address, the president, M. J. Dumas, sketched the history of the British Association, pointing out the great services rendered by that body in popularizing science. Similar results are to be expected from the French Association. Of the place occupied by science in modern life, he said: "Natural science is no longer content with the contemplative attitude which sufficed for Newton and Laplace. Science is now mixed up with all the personal acts of our existence; she interferes in all measures of public interest; industry owes to her its immense prosperity; agriculture is regenerated under her fostering care; commerce is forced to take her discoveries into account; the art of war has been transformed by her; politics is bound to admit her into its councils for the government of states. How could it be otherwise? Have not mechanics, physics, chemistry, the natural sciences, become intelligent and necessary agents for the creation of wealth by labor? If comfort is more universal, the life of man more prolonged, wealth better distributed, houses more commodious, furniture and clothing cheaper, the soldier better armed, the finances of the state more prosperous, is it not to the sciences that all this progress is due? . . . Whether we wish it or not, we must needs accept Science as a companion, to possess her or to be possessed by her. If you are ignorant, you are her slave; if you are skilled, she obeys you. The future belongs to science; unhappy are they who shut their eyes to this truth."

Japanese Metallurgy.—A writer in the *Japan Mail* describes as follows the Japanese method of obtaining mercury from its sulphide (cinnabar): The cinnabar is first

powdered by means of an iron, boat-shaped mortar, with a circular knife. It is then washed to remove the foreign matter, and to obtain the cinnabar in a finely-powdered state. This is, after being dried, mixed with an equal weight of half-burned charcoal (half coal and half ashes), and the whole is put into an iron pot, which is carefully covered with a round iron cover. This cover has in the middle a round opening, into which a curved tube of iron is fixed and cemented with a mixture of loam, salt, and a little water, the other extremity of the tube ending in a pot filled with cold water. The whole tube is wrapped in some fibrous substance, and kept cool by aid of cold water. The whole is generally heated on a small open charcoal furnace, the quicksilver distilling into the pot of water. This process is founded on the fact that the sulphur of the cinnabar is retained by the ashes, and perhaps, also, by the iron of the inner surface of the pot, the mercury evaporating by the heat. This quicksilver is, however, not pure, but always contains a small quantity of foreign metals (lead, copper, etc.).

Action of Light on Selenium.—The action of light in modifying the electrical conducting power of selenium was first observed by May, a telegraph-operator at Valencia, Ireland, who communicated the facts to Willoughby Jones in 1873. The latter having fully confirmed the observations of May, the attention of physicists, both in England and Germany, was drawn to the subject. Within the last twelve months it has been made matter of special inquiry by Prof. Adams and by Dr. Werner Siemens, each carrying on his investigations independently of the other. The results obtained by Siemens are set forth in a lecture delivered at the London Royal Institution by his kinsman, C. W. Siemens. He exhibited the action of light by a contrivance of Dr. Werner Siemens, in which the selenium was in a form in which the surface-action of light can produce its maximum effect. Two spirals of thin wire (iron or platinum) are laid on a plate of mica in such a way that the wires lie parallel without touching. While in this position a drop of fluid selenium is made to fall upon the plate, filling the interstices between the wires; and, before the selenium has had time to harden, another thin plate of mica is pressed down upon it so as to give firmness to the whole. The two protruding ends of the spirals serve to insert this selenium element in a galvanic circuit. Mr. Siemens calls this disk his "sensitive element." The whole arrangement is no larger than a sixpence. Its action was shown in this way: It was placed in a galvanic circuit, at one end being a Daniell cell, and at the other a delicate index galvanometer. The "disk" was first inclosed in a dark box; the circuit was "made," but no electricity passed through—no movement of the index was seen. The "disk" was then exposed to light; still no action was apparent. Another disk was taken that had been kept in boiling water for an hour, and gradually cooled. In the dark box it gave a slight passage to electricity as indicated by the index, but as soon as the light was admitted the index registered a great passage of electricity. Another disk heated to 210° C., and allowed to cool, was then used, and a greater action still was apparent with this. Dr. Werner Siemens has worked at the meaning of this, but without tables and diagrams it is not possible to convey an adequate idea of his results. The basis of the change in condition seems to lie in the fact of the extent to which the selenium is heated, for, when again allowed to cool, its behavior depends on the extent to which it has been heated. The experiment was shown of the effect of different parts of the spectrum on a disk. The actinic ray produces no effect, but the influence increases as we approach the red end. A selenium photometer was also shown in action, the principle of which is to compare the relative effects of two lights in affecting the conditions for the passage of electricity. At the end of the lecture a most interesting little apparatus was put at work, which Mr. Siemens calls a selenium "eye." There is a small hollow ball, with two apertures opposite to each other. In one is placed a small lens, one and a half inch diameter, and at the other a "disk." The disk is connected with a Daniell cell and a galvanometer, and this represents the retina. There are two slides

which represent the eyelids. The action of light on the disk is indicated on the galvanometer. Not only was this shown to be sensitive to white light, but sensitive in different degrees to different colors. Mr. Siemens suggested it would not be difficult to arrange a contact and electro-magnet in connection with the galvanometer in such a manner that a powerful action of light would cause the automatic closing of the eyelids, and thus imitate the spontaneous brain-action of blinking the eyelids in consequence of a flash of light. To physiologists this analogy may be suggestive regarding the important natural functions of the human frame.

Effect of Alcohol on Brain-Substance.—When brain-substance is placed in alcohol, it loses its water and its mobility of particles, and becomes more solid and firm. The question here arises, Is this thing possible with the living brain? Is it possible that, in cases of delirium tremens, so much alcohol has been consumed as, by its diffusion through the brain, it has robbed nerve-matter of its mobile character, and consequently of its power to throw off the products of its life-functions? That alcohol may, in this way, act upon the brain of the inebriate, is an opinion which, as yet, can hardly be demonstrated directly; but an experiment made by Mr. Charles T. Kingzett seems to render it highly probable. He places in a dilute solution of alcohol pieces of brain-substance derived from the ox, at the temperature of the blood, viz., 100° Fahr. At this temperature it is digested for some hours, and the liquid is then filtered. On cooling, the filtrate throws down a white deposit of matter which the alcohol has dissolved—a phenomenon which would seem to indicate some actual truth in Shakespeare's words, "O that men should put an enemy in their mouths to steal away their brains!"

Foray of an Army of Ants.—A writer in *Land and Water* gives an interesting account of a foray by an army of ants, which he witnessed in South Africa. This army, estimated to number about 14,000 ants, started from their home in the mud walls of a hut, and marched out in the direction of a small mound of fresh earth in the vicinity. The head of the column halted on reaching the foot of the mound, and the remainder of the force did likewise till the entire army was assembled. Then the forces were divided: one part remained at the foot of the mound and ran round and round it; the rest mounted to the top, and some of them entered the loose earth and speedily returned, each bearing a young grasshopper or cricket, dead, which he deposited upon the ground and returned for a fresh load. Those who had remained on the outside of the mound took up the crickets as they were brought out of the earth, and bore them down to the base of the hill, returning for a fresh load. Soon the contents of the mound seemed to be exhausted, and then the whole force returned home, each carrying his burden of food for the community. Here was a regular foray, planned and executed with military precision, the country surveyed, and the depot of provisions known accurately before the march was made; at the mound, prudential division of labor, and care taken that none of the victims should escape.

Remedy for Cold in the Head.—Dr. David Ferrier, having used with great success trisnitrate of bismuth to cure "cold in the head," sends to the *Lancet* a communication in which he warmly commends the employment of bismuth, either alone or in conjunction with other drugs, in the treatment of nasal catarrh. Bismuth of itself being heavy, and difficult to inhale, it is advisable, he writes, to combine it with acacia-powder, which increases the bulk, and renders the powder more easily inhaled, while the secretion of the nostrils causes the formation of an adherent mucilaginous coating, of itself a great sedative of an irritated surface. The sedative effect is greatly strengthened by the addition of hydrochlorate of morphia, which speedily allays the feeling of irritation and aids in stopping the reflex secretion of tears. He proposes the following formula: Hydrochlorate of morphia, two grains; acacia-powder, two drachms; trisnitrate of bismuth, six drachms. Of this powder one-quarter or one-half may be taken as snuff in the course of twenty-four hours. The inhalations should be commenced as soon as the

symptoms of catarrh begin to show themselves, and should be used frequently at first, so as to keep the interior of the nostrils constantly well coated. The powder checks the flow of mucus, and stops the sneezing. It causes scarcely any perceptible sensation. A slight smarting may occur if the mucous membrane is much irritated and inflamed, but it rapidly disappears. After a few sniffs of the powder, a perceptible amelioration of the symptoms ensues, and in the course of a few hours, the powder being inhaled from time to time, all the symptoms may have disappeared.

Evolution of the Horse.—Prof. Huxley devotes the sixth and last lecture of a course upon the origin of existing vertebrate animals to considering the evidences of the evolution of the horse. After tracing the genealogy of the horse from Orohippus, through Palæotherium, Hipparion, etc., to Equus, the author remarks as follows: "The evidence is conclusive as far as the fact of evolution is concerned, for it is preposterous to assume that each member of this perfect series of forms has been specially created; and if it can be proved, as the facts certainly do prove, that a complicated animal like the horse may have arisen by gradual modification of a lower and less specialized form, there is surely no reason to think that other animals have arisen in a different way. This case, moreover, is not isolated. Every new investigation into the Tertiary mammalian fauna brings fresh evidence, tending to show how the rhinoceros, the pigs, the ruminants, have come about. Similar light is being thrown on the origin of the carnivora, and also, in a less degree, on that of all the other groups of animals. It is not, however, to be expected that there should be, as yet, an answer to every difficulty, for we are only just beginning the study of biological facts from the evolutionary point of view. Still, when we look back twenty years to the publication of the 'Origin of Species,' we are filled with astonishment at the progress of our knowledge, and especially at the immense strides it has made in the region of paleontological research. The accurate information obtained in this department of science has put the *fact* of evolution beyond a doubt; formerly the great reproach to the theory was, that no support was lent to it by the geological history of living things; now, whatever happens, the fact remains that the hypothesis is founded on the firm basis of paleontological evidence."

Wood Pavements.—After a very thorough investigation of the advantages possessed by different kinds of pavements—granite, asphalt, and wood—the corporation of London has decided in favor of the last. The report of the city engineer shows that a horse traveling on a granite pavement may be expected to fall once for every one hundred and thirty-two miles traveled, on asphalt once in one hundred and ninety-one miles, and on wood once in four hundred and forty-six miles. The injury sustained by the animal is also far less serious from a fall upon wood than upon asphalt or upon granite. The mode of constructing wooden pavements in London appears to differ from that which has obtained in this country. The surface-water is kept out by means of a layer of asphalt, and there is a flooring of planks as a superstructure, which gives great elasticity, and by distributing the weight equally over a considerable area, adds to the power of endurance of the pavement. This decision of the London Corporation will occasion surprise on this side of the water, where wooden pavements have been pronounced an utter failure. It remains to be seen whether good material and careful construction will avail to remove the capital objection to wood as a material for pavements—its liability to speedy decay.

The Ice Age in Great Britain.—In a paper on the Ice age in Great Britain, R. Richardson cites facts with regard to the shallow depth of the ocean between Great Britain and Iceland and Greenland on the one side, and over the German Ocean on the other, and adduces reasons for holding that in the glacial era this region was *terra firma;* that the glaciers of Great Britain came over this emerged land from the north and west; and that the cold of the glacial era was due, in part at least, to the closing thus of the Arctic and exclusion of the Gulf Stream. The facts appear to war-

rant these conclusions. We give them as stated briefly in the *American Journal of Science:*

"The depth between Britain and Iceland mostly does not exceed 100 fathoms, and nowhere exceeds 1,000; one tract of sea, extending in a straight line from the eastern coast of Greenland, *via* Iceland and Faroe, to Scotland, does not exceed 500 fathoms. The depth of the sea in the English Channel is only about 20 fathoms, and the average depth of the German Ocean is not over 40 fathoms. The depth between Britain and Greenland is small compared with the average depth of the Atlantic. According to the author, one of the oscillations of level, such as have occurred over the earth's surface, had the effect to unite Britain and Northern Europe with Greenland and the arctic regions, to give the polar ice-fields access to Europe, to divert the course of the Gulf Stream and free Northwestern Europe from its influence, and, in conjunction probably with some diminution in the influence of the sun, to produce a glacial epoch."

Pet Snakes.—Frank Buckland communicates to *Land and Water* a very interesting notice of "Cleo," a pet boa-constrictor. This animal was of the kind called "painted boa," and had come from Brazil. Its length was seven feet five inches, and its weight nine pounds. Cleo came into the possession of Mr. Mann, a friend of Mr. Buckland's, in 1870, and from that time till its death was his constant companion. Her food consisted of pigeons, of which she took on the average one a week. If a pigeon were offered to her when she was not hungry, she would take but little notice of it. If the two were left together for a while, they became friends. Neither pigeons nor any other animal ever showed any fear of this serpent.

She always "killed her bird" instantaneously, seizing it by the beak, and breaking its neck by a rapid movement. She *never* crushed her prey to death, but invariably waited to see that it was motionless before laying her coils upon it. The constricting power was reserved for *mastication*, and was very sufficient for that purpose.

"We have, in traveling," writes Mr. Mann, "carried her about with us, both in railway-carriages and hotels, unsuspected by others, and no amount of inconvenience or discomfort appeared to distress her so long as we were near. She thoroughly understood the joke of keeping concealed when strangers were present. It was only when we were alone, or with our own family, that she came forth of her own accord to join the conversation. She never avoided children, but would allow them to take liberties which she would never have borne from any other stranger. When offended in any way, she simply walked off to some inaccessible corner, and waited the departure of the offender.

"I do not remember any young child showing the slightest fear when Cleo came to make acquaintance.

"The manner of Cleo's death was so much in accordance with her character that few of her friends will be surprised at what I have to tell.

"During last autumn I was laid up with a very serious illness. At first Cleo appeared to enjoy my being at home all day long, but soon began to understand, principally from my wife's anxiety, that there was something the matter, and she refused food. One night she came to my bed to talk to me as usual, but I was too ill to take any notice of her (indeed, I could neither move nor speak). She tried in vain to make me respond to her caresses, and, after a while, returned to her own bed, refused not only food, but water, and died within a day or two. To any one that knew her it was visible that she was suffering grief, as a dog is sometimes known to do under similar circumstances."

The Northerly Winds of California.—In a paper on the northerly winds of the great central valley of California, Mr. J. H. C. Bonte attributes to the prevalence of these winds the peculiar dry and moderately exhilarating climate of that region. Further, he asserts that without the north winds, and with the consequent increase of moist heat, the vegetation now cultivated in the valley would be crowded out by dense tropical growths. It is reasonable to believe that the desiccating power of the north wind, by preventing and dissipating the noxious exhalations of animal matter, acts as a preventive of disease. The north winds, following the rainy season, by drying and baking the soil, dissolve and pulverize its particles, thus freeing its productive powers. Fineness of fibre and concentrated nutriment are imparted to all the vegetable growths of the valley by the north wind, and it is possible that the grapes and strawberries of California may receive their delicate flavor from the same source. Cereal grains are made solid and flinty by this influence, and thus enabled to resist the damaging effects of moisture. The comparative exemption of the valley of California from the ravages of the weevil doubtless arises from the desiccating

power of the north wind; and the same cause checks the growth of fungi. The economical value of the north wind is discernible in its power to preserve from rapid decay houses, barns, fences, etc., and the same influence must protect iron from destructive rusts.

Effects of Lightning on Different Species of Trees. — The effects of lightning on various species of trees have been made a subject of investigation by Daniel Colladon, who communicates to the Geneva Society of Natural History the results of his observations. He states that, when a poplar is struck, all the upper part of the tree remains perfectly sound and green. The height above the ground at which the injuries appear does not, in large poplars, exceed the third of the tree's height. These injuries commence immediately below the junction of the strong branches with the trunk. In general they do not reach quite to the ground. It is always the tallest poplar that is struck. In some cases the storm will pass over trees of other species, and will explode on poplars, though they be of less height. M. Colladon has never met with any traces of carbonization. The cases in which several poplars have been injured by a single discharge of lightning are rare. One such case is recorded by the author where three poplars were damaged by the same stroke. These trees stood in a straight line, and about twelve feet distant from each other.

How they teach Geology in Rome.—The eminent archæologist, G. Mortillet, gives an amusing account of a class-lecture on geology which he once attended in the Roman University of the Sapienza. "I succeeded," he writes, "not without difficulty, in getting leave to be present at a lecture on geology. I was introduced into a large hall; in the middle stood a small table, at which four persons were seated. On the one side sat the professor in an arm-chair, and on the other three students in common chairs. Near the professor's seat was a more comfortable arm-chair for the inspecting prelate, who from time to time came to see that the teaching went on aright. As a stranger supposed to be well-disposed, I was honored with a seat in the grand arm-chair. I expected to listen to an interesting lecture in good Italian; the more, inasmuch as the professor, Ponzi, now a Senator of Italy, is a distinguished man, and a *savant* of repute. But I was disappointed. The professor, for upward of half the time of the lesson, was obliged to dictate—for such was the rule—his lecture, which had been written in advance in Latin, and revised and corrected by the censor. During the latter half he was permitted to give in Italian explanations of the dictated paragraphs; but he was not at liberty to diverge from his text, nor could the students take notes. These things I have seen with my own eyes at Rome under the reign of Pius IX., author of the 'Syllabus.'"

Effects of Compressed Air on Animals.—The mechanical effects of compressed air upon the animal economy, as ascertained by Bert, are to cause a lowering of the diaphragm and liver, and a consequent increased pulmonary vital capacity; this effect, while gradual in its production, lasts long after the subject is withdrawn from the compressed-air bath. Pravaz finds that the heart's action is at first increased, and then lessened, the pulse first becoming more rapid, and then slower, but never falling below the rate at normal pressure. The respirations are diminished during immersion, but on removal of the increased pressure they rise in frequency and in direct proportion to the degree of compression. There is an increase in the amount of urea excreted, but this increase diminishes the longer the sojourn in the compressed air. There is at the same time an increase in the amount of carbonic acid expired. The temperature of the body rises above the normal at first, and then falls as the immersion is prolonged. These varying effects are due, Pravaz thinks, to the two influences of inward atmospheric pressure and hyper-oxygenation, the former tending to diminish the circulation and the organic changes, and the other to increase them.

Occurrence of Nickel-Ores.—Nickel-ores occur in great abundance in New Caledonia, and are being actively worked. These ores in no way resemble those from which nickel

has hitherto been extracted, being silicates of nickel and magnesia, while the others are arsenio-sulphurets. They are found in serpentine rocks, which are very abundant in various parts of the island, associated with diorites, amphibolites, etc. Sometimes they appear on the various rocks as a beautiful green coating; sometimes they penetrate the rocks, giving them a more or less intense color; sometimes they form therein threads, which may assume the importance and regularity of veins; and sometimes, again, they occur in pockets. As might have been expected, the nickel is associated with iron, chrome, and cobalt, these metals, especially the two former, being very abundant; their stratification is analogous to that of nickel, except where cobalt is met with. The latter metal is associated with manganese, forming pure masses, of greater or less extent, in the midst of friable arenaceous rocks, composed of feldspathic and magnesian detritus.

Age of Trees in Relation to Time of Leafing.—In the course of a discussion, in the Paris Académie des Sciences, of the question whether the annual buds of a tree, as it grows old, preserve the characters of youth or share in the old age of the individual which produces them, it was stated that, according to observations made by Prof. Decaisne on the *Robinia pseudacacia* (common locust) of the Muséum d'Histoire Naturelle, the time of leafing does not vary with age. At Pisa, results a little different were obtained; there the gingko (*Salisburia adiantifolia*) and the walnut have been found to produce their leaves earlier in the season from year to year as they have advanced in age. On the contrary, the *Æsculus hippocastanum*, or horse-chestnut, is more tardy in proportion as it grows older. M. de Candolle, who was present at the meeting of the Academy, quoted observations carefully made every year since 1808 on two chestnut-trees at Geneva; these trees have leaved invariably between the ninety-third and the ninety-sixth day of the year. He further quoted the instance of a vine growing at Ostend. This vine has been observed during thirty-three years, and during the first eleven years it leaved on the one hundred and twenty-seventh day of the year; in the second period of eleven years, on the one hundred and twentieth; in the third, on the one hundred and sixth. Thus there would seem to be a continuous progression, the vine becoming more precocious in proportion to its advance in age.

Effects of Electricity on Particles suspended in Liquids.—Some interesting observations by Holtz on the effects of electricity on particles suspended in liquids are recorded in *Poggendorff's Annalen.* In giving an account of these observations, Holtz remarks that the "migration" of particles suspended in a liquid, subjected to electric currents, has long been known, and was thoroughly investigated by Quincke. But in all cases of such motion Holtz finds that there is, at the same time, a clinging of particles to one of the poles. This is sometimes so evident that one might construct an electroscope on this principle for ascertaining the polarity. Especially notable is the tendency of *semen lycopodii* in insulating liquids, particularly sulphuric ether, to cover the negative pole with a thick coating; while sulphur, cinnabar, or sulphide of antimony, in the same liquid, only coats the positive pole. A simple medicine-glass suffices for the experiment, a conductor or half-conductor being introduced through the stopper. The glass is held in the hand, and the conductor brought to an electric machine; the phenomenon then occurs. It is better, of course, to have the bottom perforated for insertion of the second pole, or to use an open glass, with the two poles pushed down into it. Either a frictional or an influence machine may be used.

Have Bees a Sense of Hearing?—Though the best observers deny to bees the possession of a sense of hearing, a writer in *Newman's Entomologist* relates an instance in which a hive of bees appear to have heard the summons of their queen. A swarm of bees had been gathered into a hive, which was allowed temporarily to rest upon a table. On lifting the hive, in order to set it upon the hive-board, the portion of the table on which the hive had stood was found to be covered with bees, which soon began to run about, from their having been

suddenly disturbed. The hive was now placed on the hive-board, with the entrance toward the bees. For a little while they continued to run about, as if bewildered, but then was heard a peculiar vibrating and buzzing sound proceeding from the hive. In an instant all the bees faced about, with their heads toward the hive, and all marched into it in regular procession.

A New Respirator.—A new mask for filtering dust out of the atmosphere, and intended for use by workmen who follow sundry unhealthy trades, has been devised by Dr. B. W. Richardson. Having tried various substances in order to find a good filter, he gives the preference to feathers. The advantages of feathers as filters of dust are many: they are light, they separate perfectly, admitting air in any quantity while excluding dust, and they absorb water less perhaps than any other porous flexible substance. They have the further advantage of being cheap, and of being easily made up into filters. In constructing his mask he connects the light feathers drawn from the leg-plumage of the pheasant along a line of tape. This band he wraps around the perforated breathing-tube of the mask, so that the feathers fall over the perforations. In inspiration the feathers come down over the perforations, filtering the air as it enters, while in expiration they are blown out from the tube as feather-valves.

Bat-Guano.—In reply to a circular of inquiry addressed to numerous correspondents in the Southern States, Mr. McMurtrie, chemist to the United States Department of Agriculture, received a number of letters describing deposits of "bat-guano." Near Georgetown, Williamson County, Texas, there is a deposit supposed to amount to hundreds of tons, many apartments in the cave in which the excrement is found being filled to the mouth. Near Tuscumbia, Alabama, is a deposit estimated to be worth $20,000. A cave near San Antonio, Texas, is supposed to contain 15,000 or 20,000 tons of this guano, and the store is annually increasing. Samples from these and other deposits have been analyzed by Mr. McMurtrie. Most of them he found to contain both ammonia and nitrates. Under the microscope the material is seen to consist of the remains of the hard parts of insects in a finely-comminuted condition, which are the source of its nitrogenous constituents. As a fertilizer this guano compares favorably with the fish-products manufactured in New England, and even with Peruvian guano.

Prof. Marsh and his Paleontological Work.—Prof. O. C. Marsh, in a lecture to the graduating class of Yale College, summed up the main results of his paleontological researches in the Rocky Mountains. A syllabus of the lecture is published in the *American Journal of Science.* His conclusions as to the size and growth of the brain in mammals, from the beginning of the Tertiary to the present time, may be briefly stated thus: 1. All tertiary mammals had small brains. 2. There was a gradual increase in the size of the brain during this period. 3. This increase was mainly confined to the cerebral hemispheres. 4. In some groups the convolutions of the brain have gradually become more complicated. 5. In some the cerebellum and olfactory lobes have even diminished in size. There is some evidence that the same law of brain-growth holds good for birds and reptiles from the Cretaceous to the present time. Some additional conclusions in regard to American tertiary mammals as far as now known are as follows: 1. All the ungulata from the eocene and miocene had upper and lower incisors. 2. All eocene and miocene mammals had separate scaphoid and lunar bones. 3. All mammals from these formations had separate metapodial bones. At the conclusion of the lecture Prof. Marsh announced that his work in the field was essentially completed, and that all the fossil remains collected and in part described were now in the Yale College Museum. In future he should devote himself to their study and full description, and he hoped at no distant day to make public the complete results.

Seed-Production of the Sugar-Beet.—From experiments made by Corenwinder, it appears that when beet-roots are planted for the sake of seed, they, on first sprouting, part with a certain quantity of their

sugar, which goes to support the young leaves. From this time forward until the moment when the rudiments of the seeds appear, the sugar remains in the root. Hence it would appear that the carbon requisite for the formation of the stems and leaves, which during this period attain a great development, comes mostly, if not entirely, from the atmosphere. From the time when the seeds appear, the sugar in the root disappears rapidly, and when the seed is fully ripe there is no more left.

The Kauri Pine.—The kauri pine is one of the chief timber-trees of New Zealand. These trees in some instances have been found fifteen feet in diameter and one hundred and fifty feet in height. In some kauri trees the wood is prettily marked or mottled, and is in great demand for cabinet-making. The timber is also valuable for ship-building. The kauri does not grow farther south than latitude 37° 30′. The gum which exudes from this tree is an article of commerce. Over a large area of land which has been exhausted by kauri forests in past ages, and is now barren, the gum which has exuded from the dead trees is found at a depth of from two to three feet. This gum is valuable in the manufacture of varnish. During the years 1870, 1871, and 1872, no less than 14,276 tons of the gum were exported, amounting in value to nearly half a million pounds sterling. The Maoris bring a considerable quantity to market, and the proceeds thus obtained enable them to procure the comforts of dress and living to which they have now become accustomed.

An Important Sanitary Fact.—The following interesting statement is made by Dr. Littlejohn, Medical Officer of Health for Edinburgh: "Edinburgh consists of two distinct towns, an old and a new, but with very different populations. The new town is inhabited by the better classes, and is preëminently a water-closet town; whereas the old town consists for the most part of overcrowded tenements, in which pails are used for the reception of excreta. These pails are brought to the street daily and emptied into carts provided by the authorities. Considering the low morality of the population, the bad ventilation, the overcrowding, and the retention of the filth in the living-rooms for the greater part of the day, it might naturally have been supposed that typhoid and diphtheria would be endemic in the old town. This is not the case, however, for, despite the surrounding conditions, these diseases may be said to be practically unknown. But in the new and water-closeted town the case is quite different: typhoid and diphtheria are never entirely absent, are frequently epidemic, and it has been noticed that the ravages of these diseases have been greatest in the best houses. The lesson which this teaches is, that any system of removal cannot be sanitary unless all the excremental produce of a population is so promptly and so thoroughly removed that the inhabited place, in its air and soil, shall be absolutely without fecal impurities."

Utilization of Sewage in England.—Down to the year 1874 the sewage of the English town of Coventry (population 40,000) was cast into the river Sherbourne in an undefecated state. It rendered the stream black and disgusting, and a terrible nuisance to the neighborhood, as well as a great source of danger to health, inasmuch as the sewage, at a few miles distance, found its way into the source of the water-supply of the town of Warwick. But, by the erection of sewage-works, all this has since been remedied, and the river Sherbourne has been so purified that fishes have returned to its waters. In selecting a site for the works, advantage was taken of a fall of six feet in the nature of the ground, so as to avoid the costly expedient of pumping the sewage, and to work it throughout by gravitation. A narrow strip of comparatively valueless land along the river-bank, about thirteen acres in extent, was thoroughly drained and embanked against the rising of the river during floods. The sewage is here subjected to four processes, viz.: 1. Straining by means of mechanical strainers, thus removing the solids, which form a rich manure. 2. Chemical treatment by sulphate of alumina and milk of lime, and precipitation. 3. Filtering of the effluent water by percolation through a depth of five feet of earth. 4. Drying of the precipitate or sludge in the precipitating tanks. The cost of purifying

the entire sewage of Coventry in this way, including rent of land and interest on capital, and without deducting receipts from the sale of manure, is about 1*s.* 7*d.* per head of the population per year. But, taking into account the chemical value of the manure, the cost would be about twopence per head.

Construction of Water-Tanks.—A water-tank at the top of St. George's Hospital, in London, recently burst, inundating the wards and causing destruction of life and property. This tank, which held about thirty-four tons of water, was made of cast-iron plates half an inch thick, bolted together in the usual way; in form it was a square of ten feet on a side and the depth twelve feet. The thickness of the iron plates was adequate to resist the strain put upon them only on the usual condition of the employment of tie-bars and nuts of the needed strength. But, instead of adopting the proper plan of bolting these tie-bars directly to the flanges by which the plates themselves were bolted together, thin plates of wrought-iron, only one-quarter of an inch thick, were bolted to these flanges, and the tie-bars were attached to cross-pieces that ran through holes in these plates. The cross-pieces were so short that on the least disturbance one end might slip out of its place, leaving the entire stress on the other end and on the thin plates in which it rested. As was to be expected, the plates gradually rusted, and, when the corrosion had advanced so far as to allow the bolt to be torn away by that strain on the sides of the tank which the cross-bars were intended to resist, the tank tore in two, and the water made its escape.

Movements of "Cold Waves."—Prof. Loomis, of Yale College, contributes to the *American Journal of Science and Arts*, for July, the fifth of his valuable series of papers on "Meteorology."

In a former paper he presented facts showing the origin and probable cause of extremely low temperatures. It was found that they developed among the Rocky Mountains, and moved thence, as "cold waves," over the continent eastward. Since the publication of that paper this phenomenon has become well understood, and is now sustained by further proof. It appears that low temperatures follow in the wake of storms; or, in other words, areas of high barometer follow those of low barometer.

By low temperature is understood a degree of cold which is greatly below the mean temperature of the place or area where it prevails. Thus the cold wave of December, 1872, started in Dakota on the 16th, and the temperature fell to 15°, 25°, and finally 44°, below the mean of the month. At the same time the barometer rose to 30.64.

The cold wave moved eastward and southeastward, the barometer rising as the cold came on. The cold was extreme from the Rocky Mountains to Lake Michigan, and from latitude 38° to the British possessions.

In New York, during the last six days of the month, the depression of temperature ranged from 18° to 24° below the mean of the month.

It is quite obvious, Prof. Loomis observes, that the cold experienced in Dakota did not come from beyond the Rocky Mountains, but on the easterly side, near longitude 100°. The greatest observed cold in the instance referred to was not at the most northern stations, which strengthens the conclusion expressed in a former paper that there is a source of cold independent of the transfer of air from a higher to lower latitudes. As the cold wave moves eastward, the intensity of the cold is found to diminish.

The professor calls attention to the very interesting fact that, during the low temperature of December, 1872, the stratum of cold air was of no great thickness, probably not more than 9,000 feet, as was shown at Mount Washington. On the 26th of the month, when the cold was at its maximum over the region, it was found that the temperature was higher by 20° Fahr. at the summit of the mountain than at its base.

Further facts are presented in this paper, showing the general form of areas of low barometer and of high barometer. It was previously shown that a storm area is more or less oblong, and not in any observed case entirely circular. The same appears to be true of the cold areas.

To illustrate this a chart is given, on which lines of equal barometric pressure are drawn, the lines of highest pressure being at and near the centre of the area, but diminishing as the distance from the centre is increased. These areas have a long and a short diameter, the one being in some cases twice or thrice that of the other.

The relation of barometric pressure to rainfall receives further attention in the present paper, and the conclusions previously arrived at are fully sustained.

The rainfall is greatest while the barometric pressure at the centre of the storm is diminishing, or the storm increases in intensity while the barometer continues to fall; and, on the other hand, the storm diminishes in intensity while the barometer at the centre of the storm is rising.

The progressive movement of storms seems to be sometimes interrupted, and they remain stationary over a section of country for some days. This occurs off the coast of Newfoundland, and the cause of it is attributed to unusual precipitation of vapor. In that region the rainfall is about fifty-six inches in a year, while at two hundred miles from the coast it is only forty inches.

Preservation of Entomological Specimens.—M. Felix Plateau having recommended the use of yellow glass in the windows of rooms containing entomological collections, as a means of preserving intact the natural colors of the specimens, M. Capronnier, of the Entomological Society of Belgium, made some experiments to determine the value of this suggestion. He made five small, square boxes, each covered with a pane of yellow, violet, green, blue, or colorless glass. He then fixed in the middle of each box one of the inferior wings of *Euchelia Jacobeæ*, which are of a deep carmine color, uniform in tone. Each wing was partly covered with a band of black paper, and their position was so arranged as to leave exposed successively each of the parts during a period of fifteen, thirty, and ninety days. The result was as follows: *Colorless Glass.*—The carmine tint visibly attacked after exposure of fifteen days; alteration more sensible after thirty days; after ninety days the carmine had passed into a yellowish tint. *Blue.*—The same results as with colorless glass. *Green.*—A change indicated on the thirtieth day; on the ninetieth the alteration was marked. *Yellow.*—After ninety days the carmine color almost intact. M. Capronnier accordingly concludes that a yellowish color should be preferred in every arrangement of an entomological room.

Anti-Vivisection Legislation.—In commenting upon the bill for regulating the practice of vivisection in England, *Iron* remarks upon the absurdity of a Parliament of sportsmen, supported by a mob out-of-doors, passing such a law. "Either of them" (sportsmen or mob) "for the mere pleasure of killing, or in the treatment of domestic animals, inflicts more unnecessary pain on the animal creation in one day than the whole body of physiological inquirers do in a year. The physiological worker will, if this bill passes, have to pursue his unrequited labors under the supervision of a policeman, and with a ticket-of-leave; and the result will be that original, unremunerated research of a most important class will not only continue to be pursued without endowment, but under the risk of penal servitude, the tournament of doves, pheasant-battues, and horse-racing, being all the while in full swing." A petition, signed by all the leading members of the medical profession, has been presented to the House of Lords, demanding certain modifications in the bill.

Meats cooked by Cold.—It is a fact of familiar experience that extreme cold produces in organic substances effects closely resembling those of heat. Thus, contact with frozen mercury gives the same sensation as contact with fire; and meat that has been exposed to a very low temperature assumes a condition like that produced by heat. This action of intense cold has been turned to account for economical uses by Dr. Sawiezevosky, an Hungarian chemist, as we learn from *La Nature*. He subjects flesh-meats to a temperature of *minus* 33° Fahr., and having thus "cooked them by cold," seals them hermetically in tin cans. The results are represented as being entirely satisfactory. The meat, when taken out of the cans a long time afterward, is found to be, as regards its appearance and its

odor, in all respects as inviting as at first. It is partially cooked, and needs but little treatment more to prepare it for the table. A German government commission has made experiments with this process, and two naval vessels dispatched on a voyage of circumnavigation were provisioned with this kind of meat. An establishment has been set up in Hungary for preserving meats in this way.

Causes of Putrefaction and Fermentation.—A year or two ago, Dr. J. Dougall, of Glasgow, at the Social Science Congress, held in that city, announced, as the result of investigations made by himself, that the presence of an alkali determines putrefaction in organic matter, while the presence of an acid determines fermentative changes. The same line of inquiry has been taken up since by Dr. John Day, of Victoria, Australia, who finds in Dougall's discovery an explanation of the presence in hospitals of septic poisons, giving rise to pyæmia, erysipelas, and puerperal fever. The *Sanitary Journal*, of Toronto, has a paper by Dr. Day upon this subject, the purport of which may be briefly stated as follows:

Hospitals, as usually constructed, have alkaline ceilings, alkaline walls, alkaline floors (owing to the use of soap in cleansing them). Experience has shown that pyæmia is of extremely infrequent occurrence in temporary hospitals consisting of rough wooden sheds. The incessant generation of peroxide of hydrogen by the turpentine of the wood doubtless prevents putrefactive changes, but, as turpentine always gives an acid reaction, this circumstance must greatly increase the disinfecting power of the peroxide, by determining the fermentative instead of the putrefactive decomposition of the pus-cells and other organic matter given off from the patient.

Dr. Day proposes the following method of counteracting the evils of hospital-life: The boards of the floor he would first cover with a coat consisting of equal parts of gasoline and boiled linseed-oil, to which is added a little benzoic acid. When dry, the surface is polished with a paste of beeswax, turpentine, and benzoic acid. Boards so prepared are, in his opinion, rendered permanently disinfectant. The walls and ceilings might be rubbed smooth, and coated with a varnish of paraffine or oil of turpentine; or, better still, they might be coated with silicate paint, then rubbed down and varnished. For the purpose of keeping the air pure, and destroying the pus-cells floating in it, he recommends, in addition to ventilation, the use of certain volatile substances, such as gasoline, benzine, and eucalyptus oil. The furniture should be occasionally brushed over with either gasoline or benzine, in which a little benzoic acid has been dissolved.

Cultivation of Caoutchouc-yielding Trees.—In 1870 Mr. Clements R. Markham advocated the planting of caoutchouc-yielding trees in India, and in 1873 the first attempts were made, but without success, in the Darjiling Terai and in the district of Goalpara, Assam. In the following year two plantations were made in the Kamrup district of Assam and at Charduar, at the foot of the Himalayas, in the Durrung district. The latter plantation now covers 180 acres, and in 1875 there were in it 16,401 live cuttings. The species here cultivated is the native *Ficus elastica*. Several plants of the *castilloa* tree of South America are now in a very flourishing condition at Kew Gardens, and a good supply of this species has been thence forwarded to India, where they will form the nucleus of extensive plantations. In June of the present year an agent was to have been sent out to Brazil to collect healthy young plants of the *hevea*, the tree which yields the famous Pará India-rubber. Thus provision will be effectually made against the extinction of these valuable species of plants.

Inspecting Railways by Machinery.—Attached to the rear of the paymaster's car on the Pennsylvania Railroad, says the *American Manufacturer*, is an apparatus which it is thought will work much more satisfactorily than the telegraphic instruments formerly used by the officers while making their tours of inspection. A roll of white paper, 700 feet in length, encircles a cylinder, from which it is paid out at the rate of three feet to the mile run by the car, its forward movement being regulated

by the revolutions of the nearest axle under the car. A lead-pencil placed about the centre of the paper indicates by its mark the condition of the track. The more uneven the track the longer will be the mark made by the pencil. Another way of showing the inspecting party that the track is uneven is by an horizontal piece of iron or steel, which oscillates like the pendulum of a clock as the train moves. When a very defective point is reached, the pendulum comes in contact with a metal on each side, circular in shape, which gives a sound like a bell.

Physiological Action of Coca.—The physiological action of the leaves of coca or cuca (*Erythroxylon coca*), a plant indigenous to Peru, has been the subject of much discussion lately in England. Sir Robert Christison, whose reference to the peculiar properties of this plant, in his address to the Edinburgh Botanical Society last November, gave rise to the discussion, has since taken up the subject again, in a paper read before the same society. The author gives an account of experiments made by himself and by fourteen other observers, under his instructions, with a view to determine the physiological action of coca and its principle, cocaine. His conclusions are that—1. When taken in quantities of two drachms by healthy persons it has no unpleasant, injurious, or suspicious effect whatever; 2. In a very few cases this dose of an inferior sample had no effect at all; 3. In by far the greater number of instances, and with a fine sample, extreme fatigue was removed and prevented from returning; 4. It does not in the end impair the appetite or digestion, although hunger, even after long fasting, is taken away for an hour or two; 5. The use of it is incompatible with the use of alcoholic liquors, except when the latter are taken in very small quantities.

NOTES.

In a recent Miscellany article on the cruise of the Challenger, it was stated that 4,975 fathoms, or five and a half miles, is the deepest trustworthy sounding yet made, excepting two by the Tuscarora, which showed a depth 600 feet greater. A correspondent has called our attention to a statement in No. IV. of the "Science Primer Series," to the effect that between the Azores and Bermudas a sounding had been obtained of seven and a half miles. This sounding was made twenty years ago, by Lieutenant Berryman. It was in latitude 32° 55′ north, and longitude 47° 58′ west, but it is not now regarded as trustworthy. A fruitful source of error, in this and other early soundings, was the curving of the line by currents, etc.

S. W. Burnham, Esq., of Chicago, has been appointed director of the Dearborn Observatory in that city. Mr. Burnham's contributions to observational astronomy, mostly published in the "Transactions" of the Royal Astronomical Society of London, have earned for him prominent rank among astronomers, both at home and abroad.

In a recent Italian work, measurements are given of the skulls of Dante, Petrarch, Ugo Foscolo, and Volta. Volta's skull is of extraordinary capacity. In the skull of Petrarch the Etruscan type is evident, viz., a voluminous brain, strongly developed in all its parts, and of superior psychological power; but the posterior predominates over the anterior portion, leading to the conclusion that the sentiments and instincts prevailed over the intellect.

It is asserted, by Prof. Isidor Walz, that vanadium is a general constituent of American magnetites. This conclusion is based upon examination of twenty-seven specimens of magnetites from different localities, in the United States and Canada.

In Austria, according to the *Moniteur Industriel Belge*, dynamite has been employed with success in vine-culture. In order to loosen the soil and permit access of air and moisture to the vines, cartridges of dynamite were placed in holes three metres deep, at such distances from the plants as to obviate the danger of injury to them from an explosion. The result of the explosion was that the soil was perfectly broken up to the depth of two and a half metres. Furthermore, the phylloxera completely disappeared. Certainly a novel use for explosive agents.

Died June 27th, at the age of eighty-two, Christian Gottlieb Ehrenberg, the eminent microscopist. In 1820 he was attached to a scientific expedition into Egypt, and for six years devoted himself to the microscopic investigation of the lower animal forms of that and the neighboring countries. On his return home he was appointed a professor in the medical faculty of the Berlin University. In 1829 he accompanied Humboldt to Central Asia. He was the author of numerous works upon microscopic organisms.

A company has been formed in California for the manufacture of sugar from the juice of watermelons. The process is far simpler and cheaper than that of making sugar from beets. An excellent sirup is also made from watermelon-juice. The seeds yield a sweet-oil which serves as a good substitute for olive-oil, and the residue of the sugar-manufacture is used as food for cattle.

The death is announced of Dr. Lonsdale, the pupil and biographer of Dr. Knox, the celebrated Edinburgh lecturer on anatomy. Dr. Lonsdale was also the author of some pleasant volumes on "Cumberland Worthies."

A new geological map of Scotland, by Prof. Geikie, is announced in *Nature*. The scale is ten miles to the inch. In addition to the older rocks, this map shows the position of the more important raised beaches, river alluvia, tracts of blown sand, and glacier moraines.

On June 6th and 7th a cremation congress met at Dresden. The attendance was not large. Nearly all the German governments are opposed to cremation of the dead, chiefly, as it would appear, because many of the leading advocates of this substitute for interment are pronounced radicals. The Saxon Government has refused to accept, for the benefit of the Dresden charitable institutions, the legacy of Prof. Eberhard Richter, simply because the testator had coupled with the bequest the condition that his body should be burned in a furnace at Dresden.

It is stated by Prof. de Luca, of Naples, that fruits or leaves kept in an atmosphere of carbonic acid, or of pure hydrogen, after a while begin to ferment. In the carbonic-acid atmosphere, alcohol and acetic acid are produced, and in the hydrogen mannite. In neither case do any organic ferments appear. If this observation should prove to be correct, it will lead to important consequences.

Liquid mercury has been discovered in the ground near Montpellier, and at many points in the department of Hérault, France. It is especially found in decomposing schists, but its appearance seems to be intermittent. Its presence is marked by injurious effects on the vegetation: the trees languish and die, the pasturage is spoiled, and the sheep grazing on such ground present the symptoms of mercurial poisoning.

Wire ropes of phosphor bronze are much employed in the hoisting-apparatus of mines in Europe. Such wire ropes are much stronger and more durable than those of iron or steel.

Silkworms hatched by electricity are now being reared in Italy. The superintendent of the experimental silkworm-farm at Padua has found that the hatching of silkworms may be accelerated ten or twelve days, and a yield of forty per cent. of caterpillars secured, by exposing the eggs to a current of negative electricity from a Holtz machine for eight or ten minutes. It is suggested to apply the same method to hens'-eggs and to hastening the germination of seeds.

Prof. Tait calls attention to a paper by F. Mohr, published in Liebig's *Annalen*, as early as 1837, which contains views on the nature of heat similar to those published later by Dr. Mayer. Mohr's essay is said to contain about all that is correct in Mayer, while avoiding some of his errors.

There are in Algeria 613 artesian wells, representing a total depth of over 26 kilometres (16.12 miles). The cost of these wells, including one of exceptional depth (596 metres, or about 2,000 feet), was 2,500,000 francs, or 95 francs per metre.

A living gorilla has been brought to Europe from Africa, by the remnant of the Güssfeldt expedition. The animal is in good condition, and is to be placed in the Zoölogical Gardens at Berlin. He is two years old.

The Society of Medicine and Surgery, of Bordeaux, offers a prize of 1,000 francs for the best essay upon the following subject, viz.: microscopical examination of human blood, both in the flesh and in the dry state, of the fœtus and of the adult, as compared with the blood of other mammals, from the medico-legal point of view. The essays offered must be written in either Latin or French, and submitted to the secretary of the society not later than August 31, 1879.

The "Cochin China diarrhœa" annually carries off about 1,000 men of the French army and navy. According to Dr. Normand, naval surgeon, this disease is produced by the presence in the intestines of an enormous number of entozoöns, of the new species *Anguillula stercoralis*. This entozoön is one-fourth of a millimetre in length.

George Smith, of the British Museum, famous for his Assyrian researches, died at Aleppo, August 19th, at the early age of thirty-seven years.

The *Cologne Gazette* says that Frau Theresa Fiedler von Hülsenstein, who lately died at Prague, had attained the age of one hundred and nineteen years. She was born at Hamburg in 1757, and was in her youth a maid-of-honor to the Empress Maria Theresa.

Alfred Marshall Mayer

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FERMENTATION AND ITS BEARINGS ON THE PHENOMENA OF DISEASE.[1]

By JOHN TYNDALL, LL.D., F. R. S.

IN a book with which we are all familiar, amid other wise utterances, this one occurs: "Cast thy bread upon the waters; for thou shalt find it after many days." In more senses than one this precept is illustrated by my presence here to-night. Firstly, in a general sense, I stand indebted, morally and intellectually, to the poets, historians, and philosophers, of Scotland. Secondly, in a special sense, it so happens that one of the first rootlets of my scientific life derived its nutriment from this city of Glasgow. In early youth it was my ambition to qualify myself for the profession of a civil engineer, and as I grew up one of my aids toward the attainment of this object was the study of a periodical then published in Glasgow, and called *The Practical Mechanic's and Engineer's Magazine.* In that journal I read, with an interest unfelt before, a series of essays on various departments of science—on anatomy and physiology, on geology, on mechanics, on arithmetic, and on natural philosophy and chemistry. Biography and history were also included, while in detached articles various collateral subjects were discussed, such, for example, as the difference between Newton and Leibnitz as to the measure of moving force. It was there that I first learned what Leslie had done in Edinburgh, and what Davy had done in the Royal Institution. And I can now call to mind the day and hour when the yearning to possess such apparatus as Leslie and Davy possessed, and to institute with it such inquiries as they had instituted, rose to a kind of prophetic strength within me—prophetic, for it has come to pass that my own studies as a scientific man have been in great part pursued in that particular domain which had been enriched by the discoveries of Les-

[1] A discourse delivered before the Glasgow Science Lectures Association, October 9, 1876.

lie; while the very instruments used by Davy, and which I first saw figured in the pages of the journal just mentioned, are the identical and familiar instruments with which my lectures in London are now illustrated.

Another point brought more or less home to me in those early days was the injury inflicted on the learner by bad scientific exposition. It does more than the negative damage of withholding instruction. It daunts the young mind, and saps the motive power of self-reliance. This I had experienced; and the essays referred to had this special value for me, that they not only instructed me, but gave me faith in my own capacity to be instructed. Since those days I have written books myself, and in doing so have tried to remember, and to act on the remembrance, that the labor spent in logically ordering one's thoughts, and in saying what one has to say clearly and correctly, is labor well bestowed.

The position assumed at the outset has, I think, been now made good. Glasgow in my case cast its bread upon the waters, and lo! it has returned after many days. Of the nutritive value of the return it is not for me to speak; for it may well have been soured by fortuitous ferments, mixed by the world's tainted atmosphere with the first pure leaven derived from the pages of *The Practical Mechanic's and Engineer's Magazine.*

The figure of speech here employed will become more intelligible as we proceed; for it is my desire and intention to spend the coming hour in speaking to you about *ferments*, not in a metaphorical, but in a real sense. Proper treatment is, I am persuaded, the only thing needed to make the subject both pleasant and profitable to you. For our knowledge of fermentation, and of the ground it covers, has augmented surprisingly of late, while every fresh accession to that knowledge strengthens the hope that its final issues will be of incalculable advantage to mankind.

One of the most remarkable characteristics of the age in which we live is its desire and tendency to connect itself organically with preceding ages—to ascertain how the state of things that now is came to be what it is. And the more earnestly and profoundly this problem is studied, the more clearly comes into view the vast and varied debt which the world of to-day owes to that fore-world in which man, by skill, valor, and well-directed strength, first replenished and subdued the earth. Our prehistoric fathers may have been savages, but they were clever and observant ones. They founded agriculture by the discovery and development of seeds whose origin is now unknown. They tamed and harnessed their animal antagonists, and sent them down to us as ministers, instead of rivals, in the fight for life. Later on, when the claims of luxury added themselves to those of necessity, we find the same spirit of invention at work. We have no historic account of the first brewer, but we glean from history that his art

was practised, and its produce relished, more than two thousand years ago. Theophrastus, who was born nearly four hundred years before Christ, described beer as *the wine of barley.* It is extremely difficult to preserve beer in a hot country; still, Egypt was the land in which it was first brewed, the desire of man to quench his thirst with this exhilarating beverage overcoming all the obstacles which a hot climate threw in the way of its manufacture.

Our remote ancestors had also learned by experience that wine maketh glad the heart of man. Noah, we are informed, planted a vineyard, drank of the wine, and experienced the consequences. But, though wine and beer possess so old a history, a very few years ago no man knew the secret of their formation. Indeed, it might be said that until the present year no thorough and scientific account was ever given of the agencies which come into play in the manufacture of beer, of the conditions necessary to its health, and of the maladies and vicissitudes to which it is subject. Hitherto, indeed, the art and practice of the brewer have resembled those of the physician, both being founded on empirical observation. By this is meant the observation of facts apart from the principles which explain them, and which give the mind an intelligent mastery over them. The brewer learned from long experience the conditions, not the reasons, of success. But he had to contend, and he has still to contend, against unexplained perplexities. Over and over again his care has been rendered nugatory; his beer has fallen into acidity or rottenness, and disastrous losses have been sustained of which he has been unable to assign the cause. It is the hidden enemies against which the physician and the brewer have hitherto contended that recent researches are dragging into the light of day, thus preparing the way for their final extermination.

Let us glance for a moment at the outward and visible signs of fermentation. A few weeks ago I paid a visit to a private still in a Swiss chalet; and this is what I saw: In the peasant's bedroom was a cask with a very large bung-hole carefully closed. The cask contained cherries which had lain in it for fourteen days. It was not entirely filled with the fruit, an air-space being left above the cherries when they were put in. I had the bung removed, and a small lamp dipped into this space. Its flame was instantly extinguished. The oxygen of the air had entirely disappeared, its place being taken by carbonic-acid gas.[1] I tasted the cherries; they were very sour, though when put into the cask they were sweet. The cherries and the liquid associated with them were then placed in a copper boiler, to which a copper head was closely fitted. From the head proceeded a copper tube which passed straight through a vessel of cold water, and issued at the other side. Under the open end of the tube was placed a bottle

[1] The gas which is exhaled from the lungs after the oxygen of the air has done its duty in purifying the blood, the same also which effervesces from soda-water and champagne.

to receive the spirit distilled. The flame of small wood-splinters being applied to the boiler, after a time vapor rose into the head, passed through the tube, was condensed by the cold of the water, and fell in a liquid fillet into the bottle. On being tasted, it proved to be that fiery and intoxicating spirit known in commerce as Kirsch or Kirschwasser.

The cherries, it should be remembered, were here left to themselves, no ferment of any kind being added to them. In this respect what has been said of the cherry applies also to the grape. At the vintage the fruit of the vine is placed in proper vessels, and abandoned to its own action. It ferments, producing carbonic acid; its sweetness disappears, and at the end of a certain time the unintoxicating grape-juice is converted into intoxicating wine. Here, as in the case of the cherries, the fermentation is spontaneous—in what sense spontaneous will appear more clearly by-and-by.

It is needless for me to tell a Glasgow audience that the beer-brewer does not set to work in this way. In the first place the brewer deals not with the juice of fruits, but with the juice of barley. The barley having been steeped for a sufficient time in water, it is drained, and subjected to a temperature sufficient to cause the moist grain to germinate; after which, it is completely dried upon a kiln. It then receives the name of malt. The malt is crisp to the teeth, and decidedly sweeter to the taste than the original barley. It is ground, mashed up in warm water, then boiled with hops until all the soluble portions have been extracted; the infusion thus produced being called the *wort*. This is drawn off, and cooled as rapidly as possible; then, instead of abandoning the infusion, as the wine-maker does, to its own action, the brewer mixes yeast with his wort, and places it in vessels each with only one aperture open to the air. Soon after the addition of the yeast, a brownish froth, which is really new yeast, issues from the aperture, and falls like a cataract into troughs prepared to receive it. This frothing and foaming of the wort is a proof that the fermentation is active.

Whence comes the yeast which issues so copiously from the fermenting-tub? What is this yeast, and how did the brewer become in the first instance possessed of it? Examine its quantity before and after fermentation. The brewer introduces, say, 10 cwts. of yeast; he collects 40, or it may be 50 cwts. The yeast has, therefore, augmented from four to five fold during the fermentation. Shall we conclude that this additional yeast has been spontaneously generated by the wort? Are we not rather reminded of that seed which fell into good ground, and brought forth fruit, some thirty-fold, some sixty-fold, some a hundred-fold? On examination this notion of organic growth turns out to be more than a mere surmise. In the year 1680, when the microscope was still in its infancy, Leeuwenhoek turned the instrument upon this substance, and found it composed of minute globules

suspended in a liquid. Thus knowledge rested until 1835, when Cagniard de la Tour in France, and Schwann in Germany, independently, but animated by a common thought, turned microscopes of improved definition and heightened powers upon yeast, and found it budding and sprouting before their eyes. The augmentation of the yeast alluded to above was thus proved to arise from the growth of a minute plant, now called *Torula* (or *Saccharomyces*) *cerevisiæ*. Spontaneous generation is therefore out of the question. The brewer deliberately sows the yeast-plant, which grows and multiplies in the wort as its proper soil. This discovery marks an epoch in the history of fermentation.

But where did the brewer find his yeast? The reply to this question is similar to that which must be given if the brewer were asked where he found his barley. He has received the seeds of both of them from preceding generations. Could we connect without solution of continuity the present with the past, we should probably be able to trace back the yeast employed by my friend Sir Fowell Buxton today to that employed by some Egyptian brewer two thousand years ago. But you may urge that there must have been a time when the first yeast-cell was generated. Granted—exactly as there was a time when the first barley-corn was generated. Let not the delusion lay hold of you, that a living thing is easily generated, because it is small. Both the yeast-plant and the barley-plant lose themselves in the dim twilight of antiquity, and in this our day there is no more proof of the spontaneous generation of the one than there is of the spontaneous generation of the other.

I stated a moment ago that the fermentation of grape-juice was spontaneous; but I was careful to add, "in what sense spontaneous will appear more clearly by-and-by." Now, this is the sense meant: The wine-maker does not, like the brewer and distiller, deliberately introduce either yeast, or any equivalent of yeast, into his vats; he does not consciously sow in them any plant, or the germ of any plant; indeed, he has been hitherto in ignorance whether plants or germs of any kind have had anything to do with his operations. Still, when the fermented grape-juice is examined, the living *Torula* concerned in alcoholic fermentation never fails to make its appearance. How is this? If no living germ has been introduced into the wine-vat, whence comes the life so invariably developed there?

You may be disposed to reply, with Turpin and others, that, in virtue of its own inherent powers, the grape-juice, when brought into contact with the vivifying atmospheric oxygen, runs spontaneously and of its own accord into these low forms of life. I have not the slightest objection to this explanation, provided proper evidence can be adduced in support of it. But the evidence adduced in its favor, as far as I am acquainted with it, snaps asunder under the least strain of scientific criticism. It is, as far as I can see, the evidence of men

who, however keen and clever as *observers*, are not rigidly-trained *experimenters*. These alone are aware of the precautions necessary in investigations of this delicate kind. In reference, then, to the life of the wine-vat, what is the decision of experiment when carried out by competent men? Let a quantity of the clear, filtered "must" of the grape be boiled, so as to destroy such germs as it may have contracted from the air or otherwise. In contact with germless air the uncontaminated must never ferments. All the materials for spontaneous generation are there, but so long as there is no seed sown there is no life developed, and no sign of that fermentation which is the concomitant of life. Nor need you resort to a boiled liquid. The grape is sealed by its own skin against contamination from without. By an ingenious device, Pasteur has extracted from the interior of the grape its pure juice, and proved that in contact with pure air it never acquires the power to ferment itself, nor to produce fermentation in other liquids.[1] It is not, therefore, in the interior of the grape that the origin of the life observed in the vat is to be sought.

What, then, is its true origin? This is Pasteur's answer, which his well-proved accuracy renders worthy of all confidence: At the time of the vintage little microscopic particles are observed adherent, both to the outer surface of the grape and of the twigs which support the grape. Brush these particles into a capsule of pure water. It is rendered turbid by the dust. Examined by a microscope, these minute particles are seen to present the appearance of organized cells. Instead of receiving them in water, let them be brushed into the pure inert juice of the grape. Forty-eight hours after this is done, our familiar *Torula* is observed budding and sprouting, the growth of the plant being accompanied by all the other signs of active fermentation. What is the inference to be drawn from this experiment? Obviously that the particles adherent to the external surface of the grape are the veritable germs of that life which, after they have been sown in the juice, appears in such profusion. Wine is sometimes objected to on the ground that fermentation is "artificial;" but we notice here the responsibility of Nature. The ferment of the grape is in fact a parasite of the grape, and the art of the wine-maker from time immemorial has consisted in bringing—and it may be added, ignorantly bringing—two things thus closely associated by Nature into actual contact with each other. For thousands of years, what has been done consciously by the brewer has been done unconsciously by the wine-grower. The one has sown his leaven just as much as the other.

Nor is it necessary to impregnate the beer-wort with leaven to provoke fermentation. Abandoned to the contact of our common air,

[1] The liquids of the healthy animal body are also sealed from external contamination. Neither pure urine, collected fresh from the bladder, nor pure blood, drawn with due precautions from the veins, will ever putrefy in contact with pure air.

it sooner or later ferments; but the chances are, that the produce of that fermentation, instead of being agreeable, would be disgusting to the taste. By a rare accident we might get the true alcoholic fermentation, but the odds against obtaining it would be enormous. Pure air acting upon a lifeless liquid will never provoke fermentation; but our ordinary air is the vehicle of numberless germs which act as ferments when they fall into appropriate infusions. Some of them produce acidity, some putrefaction. The germs of our yeast-plant are also in the air; but so sparingly distributed that an infusion like beer-wort, exposed to the air, is almost sure to be taken possession of by foreign organisms. In fact, the maladies of beer are wholly due to the admixture of these objectionable ferments, whose forms and modes of nutrition differ materially from those of the true leaven of beer.

Working in an atmosphere charged with the germs of these organisms, you can understand how easy it is to fall into error in studying the action of any one of them. Indeed, it is only the most accomplished experimenter, who, moreover, avails himself of every means of checking his conclusions, that can walk without tripping through this land of pitfalls. Such a man is the French chemist Pasteur. He has taught us how to separate the commingled ferments of our air, and to study their pure individual action. Guided by him, let us fix our attention more particularly upon the growth and action of the true yeast-plant under different conditions. Let it be sown in a fermentable liquid, which is supplied with plenty of pure air. The plant will flourish in the aërated infusion, and produce large quantities of carbonic-acid gas—a compound, as you know, of carbon and oxygen. The oxygen thus consumed by the plant is the free oxygen of the air, which we suppose to be abundantly supplied to the liquid. The action is so far similar to the respiration of animals, which inspire oxygen and expire carbonic acid. If we examine the liquid even when the vigor of the plant has reached its maximum, we hardly find in it a trace of alcohol. The yeast has grown and flourished, but it has almost ceased to act as a ferment. And could every individual yeast-cell seize, without any impediment, free oxygen from the surrounding liquid, it is certain that it would cease to act as a ferment altogether.

What, then, are the conditions under which the yeast-plant must be placed so that it may display its characteristic quality? Reflection on the facts already referred to suggests a reply, and rigid experiment confirms the suggestion. Consider the Alpine cherries in their closed vessels. Consider the beer in its barrels, with a single small aperture open to the air, through which it is observed not to imbibe oxygen, but to pour forth carbonic acid. Whence come the volumes of oxygen necessary to the production of this latter gas? The small quantity of atmospheric air dissolved in the wort and overlying it would be totally incompetent to supply the necessary oxygen.

In no other way can the yeast-plant obtain the gas necessary for its respiration than by wrenching it from surrounding substances in which the oxygen exists, not free, but in a state of combination. It decomposes the sugar of the solution in which it grows, produces heat, breathes forth carbonic-acid gas, and one of the liquid products of the decomposition is our familiar alcohol. The act of fermentation, then, is a result of the effort of the little plant to maintain its respiration by means of combined oxygen, when its supply of free oxygen is cut off. As defined by Pasteur, fermentation is *life without air*.

But here the knowledge of that thorough investigator comes to our aid to warn us against errors which have been committed over and over again. It is not all yeast-cells that can thus live without air and provoke fermentation. They must be young cells which have caught their vegetative vigor from contact with free oxygen. But, once possessed of this vigor, the yeast may be transplanted into a saccharine infusion absolutely purged of air, where it will continue to live at the expense of the oxygen, carbon, and other constituents of the infusion. Under these new conditions its life, *as a plant*, will be by no means so vigorous as when it had a supply of free oxygen, but its action *as a ferment* will be indefinitely greater.

Does the yeast-plant stand alone in its power of provoking alcoholic fermentation? It would be singular if amid the multitude of low vegetable forms no other could be found capable of acting in a similar way. And here, again, we have occasion to marvel at that sagacity of observation among the ancients to which we owe so vast a debt. Not only did they discover the alcoholic ferment of yeast, but they had to exercise a wise selection in picking it out from others, and giving it special prominence. Place an old boot in a moist place, or expose common paste or a pot of jam to the air: it soon becomes coated with a blue-green mould, which is nothing else than the fructification of a little plant called *Penicillium glaucum*. Do not imagine that the mould has sprung spontaneously from boot, or paste, or jam; its germs, which are abundant in the air, have been sown, and have germinated, in as legal and legitimate a way as thistle-seeds wafted by the wind to a proper soil. Let the minute spores of *Penicillium* be sown in a fermentable liquid, which has been previously boiled in order to kill all other spores or seeds which it may contain; let pure air have free access to the mixture: the *Penicillium* will grow rapidly, striking long filaments into the liquid, and fructifying at its surface. Test the infusion at various stages of the plant's growth: you will never find in it a trace of alcohol. But forcibly submerge the little plant, push it down deep into the liquid, where the quantity of free oxygen that can reach it is insufficient for its needs: it immediately begins to act as a ferment, supplying itself with oxygen by the decomposition of the sugar, and producing alcohol as one of the results of the decomposition. Many other low microscopic plants act in a similar

manner. In aërated liquids they flourish without any production of alcohol, but cut off from free oxygen they act as ferments, producing alcohol exactly as the real alcoholic leaven produces it, only less copiously. For all this knowledge we are indebted to Pasteur.

In the cases hitherto considered, the fermentation is proved to be the invariable correlative of *life*, being produced by organisms foreign to the fermentable substance. But the substance itself may also have within it, to some extent, the motive power of fermentation. The yeast-plant, as we have learned, is an assemblage of living cells; but so at bottom, as shown by Schleiden and Schwann, are all living organisms. Cherries, apples, peaches, pears, plums, and grapes, for example, are composed of cells, each of which is a living unit. And here I have to direct your attention to a point of extreme interest. In 1821, the celebrated French chemist, Bérard, established the important fact that all ripening fruit, exposed to the free atmosphere, absorbed the oxygen of the atmosphere, and liberated an approximately equal volume of carbonic acid. He also found that, when ripe fruits were placed in a confined atmosphere, the oxygen of the atmosphere was first absorbed, and an equal quantity of carbonic acid given out. But the process did not end here. After the oxygen had vanished, carbonic acid, in considerable quantities, continued to be expired by the fruits, which at the same time lost a portion of their sugar, becoming more acid to the taste, though the absolute quantity of acid was not augmented. This was an observation of capital importance, and Bérard had the sagacity to remark that the process might be regarded as a kind of fermentation.

Thus the living cells of fruits can absorb oxygen and breathe out carbonic acid, exactly like the living cells of the leaven of beer. Supposing the access of oxygen suddenly cut off, will the living fruit-cells as suddenly die, or will they continue to live as yeast lives, by extracting oxygen from the saccharine juices round them? This is a question of extreme theoretic significance. It was first answered affirmatively by the able and conclusive experiments of Lechartier and Bellamy, and the answer was subsequently confirmed and explained by the experiments and the reasoning of Pasteur. Bérard only showed the absorption of oxygen and the production of carbonic acid; Lechartier and Bellamy proved the production of alcohol, thus completing the evidence that it was a case of real fermentation. Influenced by his theoretic views, so full was Pasteur of the idea that the cells of a fruit would continue to live at the expense of the sugar of the fruit, that once in his laboratory, while conversing on these subjects with M. Dumas, he exclaimed, "I will wager that if a grape be plunged into an atmosphere of carbonic acid, it will produce alcohol and carbonic acid by the continued life of its own cells—that they will act for a time like the cells of the true alcoholic leaven." He made the experiment, and found the result to

be what he had foreseen. He then extended the inquiry. Placing under a bell-jar twenty-four plums, he filled the jar with carbonic-acid gas; beside it he placed twenty-four similar plums uncovered. At the end of eight days he removed the plums from the jar, and compared them with the others. The difference was extraordinary. The uncovered fruits had become soft, watery, and very sweet; the others were firm and hard, their fleshy portions being not at all watery. They had, moreover, lost a considerable quantity of their sugar. They were afterward bruised, and the juice distilled. It yielded six and a half grammes of alcohol, or one per cent. of the total weight of the plums. Neither in these plums, nor in the grapes first experimented on by Pasteur, could any trace of the ordinary alcoholic leaven be found. The fermentation was the work of the living cells of the fruit itself, after air had been denied to them. When, moreover, the cells were destroyed by bruising, no fermentation ensued. The fermentation was the correlative of a vital act, and it ceased when life was extinguished.

Lüdersdorf was the first to show by this method that yeast acted, not, as Liebig had assumed, in virtue of its *organic*, but in virtue of its *organized*, character. He destroyed the cells of yeast by rubbing them on a ground-glass plate, and found that with the destruction of the organism, though its chemical constituents remained, the power to act as a ferment totally disappeared.

One word more in reference to Liebig may find a place here. To the philosophic chemist thoughtfully pondering these phenomena, familiar with the conception of molecular motion, and the changes produced by the interactions of purely chemical forces, nothing could be more natural than to see in the process of fermentation a simple illustration of molecular instability, the ferment propagating to surrounding molecular groups the overthrow of its own tottering combinations. Broadly considered, indeed, there is a certain amount of truth in this theory; but Liebig, who propounded it, missed the very kernel of the phenomena when he overlooked or contemned the part played in fermentation by microscopic life. He looked at the matter too little with the eye of the body, and too much with the spiritual eye. He practically neglected the microscope, and was unmoved by the knowledge which its revelations would have poured in upon his mind. His hypothesis, as I have said, was natural—nay, it was a striking illustration of Liebig's power to penetrate and unveil molecular actions; but it was an error, and as such has proved an *ignis fatuus* instead of a *pharos* to some of his followers.

I have said that our air is full of the germs of ferments differing from the alcoholic leaven, and sometimes seriously interfering with the latter. They are the weeds of this microscopic garden which often overshadow and choke the flowers. Let us take an illustrative case. Expose boiled milk to the air. It will cool, and then turn

sour, separating like blood into clot and serum. Place a drop of this sour milk under a powerful microscope and watch it closely. You see the minute butter-globules animated by that curious quivering motion called the Brownian motion.[1] But let not this attract your attention too much, for it is another motion that we have now to seek. Here and there you observe a greater disturbance than ordinary among the globules; keep your eye upon the place of tumult, and you will probably see emerging from it a long, eel-like organism, tossing the globules aside and wriggling more or less rapidly across the field of the microscope. Familiar with one sample of this organism, which from its motions receives the name of vibrio, you soon detect numbers of them. It is these organisms which, by decomposing the milk, render it sour. This vibrio is in fact the butyric-acid ferment, as the yeast-plant is the alcoholic ferment. Keep the vibrio and its germs out of your milk and it will never turn sour. But, instead of becoming sour, milk may become putrid. This is due to the action of another living ferment. Examine your putrid milk microscopically, and you find it swarming with organisms much shorter than the vibrios, and manifesting sometimes a wonderful alacrity of motion. Keep this smaller organism and its germs out of your milk and it will never putrefy. Expose a mutton-chop to the air and keep it moist; in summer weather it soon stinks. Place a drop of the juice of the fetid chop under a powerful microscope; it is seen swarming with organisms resembling those in the putrid milk. These organisms, which receive the common name of bacteria,[2] are the agents of all putrefaction. Keep them and their germs from your meat and it will remain forever sweet. Thus we begin to see that within the world of life to which we ourselves belong there is another living world requiring the microscope for its discernment, but which, nevertheless, has the most important bearing on the welfare of the higher life-world.

And now let us reason together as regards the origin of these bacteria. A granular powder is placed in your hands, and you are asked to state what it is. You examine it, and have, or have not, reason to suspect that seeds of some kind are mixed up in it. But you prepare a bed in your garden, sow in it the powder, and soon after find a mixed crop of docks and thistles sprouting from your bed. Until this powder was sown neither docks nor thistles ever made their appearance in your garden. You repeat the experiment once, twice, ten times, fifty times. From fifty different beds after the sowing of the powder you obtain the same crop. What will be your response to the question proposed to you? "I am not in a condition," you would say, "to affirm that every grain of the powder is a dock-seed or a thistle-seed; but I am in a condition to affirm that both dock and

[1] Which I am inclined to regard as an effect of surface tension.

[2] Doubtless organisms exhibiting grave specific differences are grouped together under this common name.

thistle seeds form, at all events, part of the powder." Supposing a succession of such powders to be placed in your hands with grains becoming gradually smaller, until they dwindle to the size of impalpable dust-particles; assuming that you treat them all in the same way, and that from every one of them in a few days you obtain a definite crop—it may be clover, it may be mustard, it may be mignonette, it may be a plant more minute than any of these—the smallness of the particles, or of the plants that spring from them, does not affect the validity of the conclusion. Without a shadow of misgiving you would conclude that the powder must have contained the seeds or germs of the life observed. There is not in the range of physical science an experiment more conclusive nor an inference safer than this one.

Supposing the powder to be light enough to float in the air, and that you are enabled to see it there just as plainly as you saw the heavier powder in the palm of your hand. If the dust sown by the air instead of by the hand produce a definite living crop, with the same logical rigor you would conclude that the germs of this crop must be mixed with the dust. To take an illustration: The spores of the little plant *Penicillium glaucum*, to which I have already referred, are light enough to float in the air. A cut apple, a pear, a tomato, a slice of vegetable marrow, or, as already mentioned, an old moist boot, a dish of paste, or a pot of jam, constitutes a proper soil for the *Penicillium*. Now, if it could be proved that the dust of the air when sown in this soil produces this plant, while, wanting the dust, neither the air nor the soil, nor both together, can produce it, it would be obviously just as certain in this case that the floating dust contains the germs of *Penicillium* as that the powders sown in your garden contained the germs of the plants which sprung from them.

But how is the floating dust to be rendered visible? In this way: Build a little chamber and provide it with a door, windows, and window-shutters. Let an aperture be made in one of the shutters through which a sunbeam can pass. Close the door and windows, so that no light shall enter save through the hole in the shutter. The track of the sunbeam is at first perfectly plain and vivid in the air of the room. If all disturbance of the air of the chamber be avoided, the luminous track will become fainter and fainter, until at last it disappears absolutely, and no trace of the beam is to be seen. What rendered the beam visible at first? The floating dust of the air, which, thus illuminated and observed, is as palpable to sense as any dust or powder placed on the palm of the hand. In the still air the dust gradually sinks to the floor, or sticks to the walls or ceiling, until, finally, by this self-cleansing process, the air is entirely freed from mechanically suspended matter.

Thus far, I think, we have made our footing sure. Let us proceed. Chop up a beefsteak and allow it to remain for two or three hours

just covered with warm water; you thus extract the juice of the beef in a concentrated form. By properly boiling the liquid and filtering it you can obtain from it a perfectly transparent beef-tea. Expose a number of vessels containing this tea to the moteless air of your chamber, and expose a number of similar vessels containing precisely the same liquid to the dust-laden air. In three days every one of the latter stinks, and, examined with the microscope, every one of them is found swarming with the bacteria of putrefaction. After three months, or three years, the beef-tea within the chamber is found in every case as sweet and clear, and as free from bacteria, as it was at the moment when it was first put in. There is absolutely no difference between the air within and that without, save that the one is dustless and the other dust-laden. Clinch the experiment thus: Open the door of your chamber and allow the dust to enter it. In three days afterward you have every vessel within the chamber swarming with bacteria, and in a state of active putrefaction. Here, also, the inference is quite as certain as in the case of the powder sown in your garden. Multiply your proofs by building fifty chambers instead of one, and by employing every imaginable infusion of wild animals and tame; of flesh, fish, fowl, and viscera; of vegetables of the most various kinds. If, in all these cases, you find the dust infallibly producing its crop of bacteria, while neither the dustless air nor the nutritive infusion, nor both together, are ever able to produce this crop, your conclusion is simply irresistible that the dust of the air contains the germs of the crop which has appeared in your infusions. I repeat, there is no inference of experimental science more certain than this one. In the presence of such facts, to use the words of a paper lately published in the "Philosophical Transactions," it would be simply monstrous to affirm that these swarming crops of bacteria are spontaneously generated.

Is there, then, no experimental proof of spontaneous generation? I answer without hesitation, *none!* But to doubt the experimental proof of a fact, and to deny its possibility, are two different things, though some writers confuse matters by making them synonymous. In fact, this doctrine of spontaneous generation, in one form or another, falls in with the theoretic beliefs of some of the foremost workers of this age; but it is exactly these men who have the penetration to see, and the honesty to expose, the weakness of the evidence adduced in its support.

And here observe how these discoveries tally with the common practices of life. Heat kills the bacteria, cold numbs them. When my housekeeper has pheasants in charge which she wishes to keep sweet, but which threaten to give way, she partially cooks the birds, kills the infant bacteria, and thus postpones the evil day. By boiling her milk she also extends its period of sweetness. Some weeks ago, in the Alps, I made a few experiments on the influence of cold upon

ants. Though the sun was strong, patches of snow still maintained themselves on the mountain-slopes. The ants were found in the warm grass and on the warm rocks adjacent. Transferred to the snow, the rapidity of their paralysis was surprising. In a few seconds a vigorous ant, after a few languid struggles, would wholly lose its power of locomotion, and lie practically dead upon the snow. Transferred to the warm rock it would revive, to be again smitten with death-like numbness when retransferred to the snow. What is true of the ant is specially true of our bacteria. Their active life is suspended by cold, and with it their power of producing or continuing putrefaction. This is the whole philosophy of the preservation of meat by cold. The fish-monger, for example, when he surrounds his very assailable wares by lumps of ice, stays the process of putrefaction by reducing to numbness and inaction the organisms which produce it, and in the absence of which his fish would continue sweet and sound. It is the astonishing activity into which these bacteria are pushed by warmth that renders a single summer's day sometimes so disastrous to the great butchers of London and Glasgow. The bodies of guides lost in the crevices of Alpine glaciers have come to the surface forty years after their interment without the flesh showing any sign of putrefaction. But the most astonishing case of this kind is that of the hairy elephant of Siberia which was found incased in ice. It had been buried for ages, but when laid bare its flesh was sweet, and for some time afforded copious nutriment to the wild beasts which fed upon it.

Beer is assailable by all the organisms here referred to, some of which produce acetic, some lactic, and some butyric acid, while yeast is open to attack from the bacteria of putrefaction. In relation to the particular beverage the brewer wishes to produce, these foreign ferments have been properly called *ferments of disease*. The cells of the true leaven are globules, usually somewhat elongated. The other organisms are more or less rod-like or eel-like in shape, some of them being beaded so as to resemble necklaces. Each of these organisms produces a fermentation and a flavor peculiar to itself. Keep them out of your beer and it remains forever unaltered. Never without them will your beer contract disease. But their germs are in the air, in the vessels employed in the brewery, even in the yeast used to impregnate the wort. Consciously or unconsciously, the whole art of the brewer is directed against them. His aim is to paralyze if he cannot annihilate them.

For beer, moreover, the question of temperature is one of supreme importance; indeed, the recognized influence of temperature is causing on the Continent of Europe a complete revolution in the manufacture of beer. When I was a student in Berlin, in 1851, there were certain places specially devoted to the sale of Bavarian beer, which was then making its way into public favor. The beer is prepared by what is called the process of *low fermentation;* the name being

given partly because the yeast of this beer, instead of rising to the top and issuing through the bung-hole, falls to the bottom of the cask; but partly, also, because it is produced at a low temperature. The other and older process, called *high fermentation*, is far more handy, expeditious, and cheap. In high fermentation eight days suffice for the production of the beer; in low fermentation, ten, fifteen, even twenty days, are found necessary. Vast quantities of ice, moreover, are consumed in the process of low fermentation. In the single brewery of Dreher, of Vienna, 100,000,000 pounds of ice are consumed annually in cooling the wort and beer. Notwithstanding these obvious and weighty drawbacks, the low fermentation is rapidly displacing the high upon the Continent. Here are some statistics which show the number of breweries of both kinds existing in Bohemia in 1860, 1865, and 1870:

	1860.	1865.	1870.
High fermentation . .	281	81	18
Low fermentation . .	135	459	831

Thus in ten years the number of high-fermentation breweries fell from 281 to 18, while the number of low-fermentation breweries rose from 135 to 831. The sole reason for this vast change—a change which involves a greater expenditure of time, labor, and money—is the additional command which it gives the brewer over the fortuitous ferments of disease. These ferments, which, it is to be remembered, are living organisms, have their activity suspended by temperatures below 10° C., and as long as they are reduced to torpor the beer remains untainted either by acidity or putrefaction. The beer of low fermentation is brewed in winter, and kept in cool cellars; the brewer being thus enabled to dispose of it at his leisure, instead of forcing its consumption to avoid the loss involved in its alteration if kept too long. Hops, it may be remarked, act to some extent as an antiseptic to beer. The essential oil of the hop is bactericidal: hence the strong impregnation with hop-juice of all beer intended for exportation.

These low organisms, which one might be disposed to regard as the beginnings of life, were we not warned that the microscope, precious and perfect as it is, has no power to show us the real beginnings of life, are by no means purely useless or purely mischievous in the economy of Nature. They are only noxious when out of their proper place. They exercise a useful and valuable function as the burners and consumers of dead matter, animal and vegetable, reducing such matter, with a rapidity otherwise unattainable, to innocent carbonic acid and water. Furthermore, they are not all alike, and it is only restricted classes of them that are really dangerous to man. One difference in their habits is worthy of special reference here. Air, or rather the oxygen of the air, which is absolutely necessary to the support of the bacteria of putrefaction, is absolutely deadly to

the vibrios which provoke the butyric-acid fermentation. This is most simply illustrated by the following beautiful observation of Pasteur: You know the way of looking at these small organisms through the microscope. A drop of the liquid containing them is placed upon glass, and on the drop is placed a circle of exceedingly thin glass; for, to magnify them sufficiently, it is necessary that the microscope should come very close to the organisms. Round the edge of the circular plate of glass the liquid is in contact with the air, and incessantly absorbs it, including the oxygen. Here, if the drop be charged with bacteria, we have a zone of very lively ones. But through this living zone, greedy of oxygen and appropriating it, the vivifying gas cannot penetrate to the centre of the film. In the middle, therefore, the bacteria die, while their peripheral colleagues continue active. If a bubble of air chance to be inclosed in the film, round it the bacteria will pirouette and wabble until its oxygen has been absorbed, after which all their motions cease. Precisely the reverse of all this occurs with the vibrios of butyric acid. In their case it is the peripheral organisms that are first killed, the central ones remaining vigorous while ringed by a zone of dead. Pasteur, moreover, filled two vessels with a liquid containing these vibrios: through one vessel he led air, and killed its vibrios in half an hour; through the other he led carbonic acid, and after three hours found the vibrios fully active. It was while observing these differences of deportment fifteen years ago that the thought of life without air, and its bearing upon the theory of fermentation, flashed upon the mind of this admirable investigator.

And here I am tempted to inquire how it is that during the last five or six years so many of the cultivated English and American public, including members of the medical profession and contributors to some of our most intellectual journals, could be so turned aside as they have been from the pure well-spring of scientific truth to be found in the writings of Pasteur? The reason I take to be, that, while against unsound logic a healthy mind can always defend itself, against unsound experiment without discipline it is defenseless. To judge of the soundness of scientific data, and to reason from data assumed to be sound, are two totally different things. The one deals with the raw material of fact, the other with the logical textures woven from that material. Now, the logical loom may go accurately through all its motions, while the woven fibres may be all rotten. It is this inability, through lack of education in experiment, to judge of the soundness of experimental work, which lies at the root of the defection from Pasteur.

I will cite an example of this mistake of judgment. Between the large-type articles and the reviews of the *Saturday Review* essays on various subjects are interpolated. On Alpine slopes and in the calm of summer evenings, while reading these brief essays, I have been

many a time impressed, not only with their sparkling cleverness, but with their deep-searching wisdom and their wealth of spiritual experience. In this central region of the *Review* the question of spontaneous generation has been taken up and discussed. The writer is not a whit behind his colleagues in literary brilliancy and logical force. But, having no touchstone in his own experience to enable him to distinguish a good experiment from a bad one, he has committed, on the point of the gravest practical import, the influence of the powerful journal in which he writes to the support of error. It is only, I would repeat, by practice among facts that the intellect is prepared to judge of facts, and no mere logical acuteness or literary skill can atone for the want of this necessary education.

We now approach an aspect of this question which concerns us still more closely, and which will be best illustrated by an actual fact. A few years ago I was bathing in an Alpine stream, and, returning to my clothes from the cascade which had been my shower-bath, I slipped upon a block of granite, the sharp crystals of which stamped themselves into my naked shin. The wound was an awkward one, but, being in vigorous health at the time, I hoped for a speedy recovery. Dipping a clean pocket-handkerchief into the stream, I wrapped it round the wound, limped home, and remained for four or five days quietly in bed. There was no pain, and at the end of this time I thought myself quite fit to quit my room. The wound, when uncovered, was found perfectly clean, uninflamed, and entirely free from pus. Placing over it a bit of gold-beater's-skin, I walked about all day. Toward evening itching and heat were felt; a large accumulation of pus followed, and I was forced to go to bed again. The water-bandage was restored, but it was powerless to check the action now set up; arnica was applied, but it made matters worse. The inflammation increased alarmingly, until finally I was ignobly carried on men's shoulders down the mountain, and transported to Geneva, where, thanks to the kindness of friends, I was immediately placed in the best medical hands. On the morning after my arrival in Geneva, Dr. Gautier discovered an abscess in my instep, at a distance of five inches from the wound. The two were connected by a channel, or *sinus*, as it is technically called, through which he was able to empty the abscess without the application of the lance.

By what agency was that channel formed—what was it that thus tore asunder the sound tissue of my instep, and kept me for six weeks a prisoner in bed? In the very room where the water-dressing had been removed from my wound and the gold-beater's-skin applied to it, I opened this year a number of tubes, containing perfectly clear and sweet infusions of fish, flesh, and vegetable. These hermetically-sealed infusions had been exposed for weeks, both to the sun of the Alps and to the warmth of a kitchen, without showing the slightest turbidity or sign of life. But two days after they were opened the

greater number of them swarmed with the bacteria of putrefaction, the germs of which had been contracted from the dust-laden air of the room. And, had the pus from my abscess been examined, my memory of its appearance leads me to infer that it would have been found equally swarming with these bacteria—that it was their germs which got into my incautiously-opened wound. They were the subtile workers that burrowed down my shin, dug the abscess in my instep, and produced effects which might well have proved fatal to me.

And here we come directly face to face with the labors of a man who has established for himself an imperishable reputation in relation to this subject, who combines the penetration of the true theorist with the skill and conscientiousness of the true experimenter, and whose practice is one continued demonstration of the theory that the putrefaction of wounds is to be averted by the destruction of the germs of bacteria. Not only from his own reports of his cases, but from the reports of eminent men who have visited his hospital, and from the opinions expressed to me by Continental surgeons, do I gather that one of the greatest steps ever made in the art of surgery was the introduction of the antiseptic system of treatment, practised first in Glasgow and now in Edinburgh, by Prof. Lister.

The interest of this subject does not slacken as we proceed. We began with the cherry-cask and beer-vat; we end with the body of man. There are persons born with the power of interpreting natural facts, as there are others smitten with everlasting incompetence in regard to such interpretation. To the former class in an eminent degree belonged the celebrated philosopher Robert Boyle, whose words in relation to this subject have in them the forecast of prophecy. "And let me add," writes Boyle in his "Essay on the Pathological Part of Physik," "that he that thoroughly understands the nature of ferments and fermentations shall probably be much better able than he that ignores them to give a fair account of divers phenomena of several diseases (as well fevers as others) which will perhaps be never properly understood without an insight into the doctrine of fermentations."

Two hundred years have passed since these pregnant words were written, and it is only in this our day that men are beginning to fully realize their truth. In the domain of surgery the justice of Boyle's surmise has been most strictly demonstrated. Demonstration is indeed the only word which fitly characterizes the evidence brought forward by Prof. Lister. You will grasp in a moment his leading idea. Take the extracted juice of beef or mutton, so prepared as to be perfectly transparent, and entirely free from the living germs of bacteria. Into the clear liquid let fall the tiniest drop of an infusion charged with the bacteria of putrefaction. Twenty-four hours subsequently the clear extract will be found muddy throughout, the turbidity being due to swarms of bacteria generated by the drop with

which the infusion was inoculated. At the same time the infusion will have passed from a state of sweetness to a state of putridity. Let a drop similar to that which has produced this effect fall into an open wound: the juices of the living body nourish the bacteria as the beef or mutton juice nourished them, and you have putrefaction produced within the system. The air, as I have said, is laden with floating matter which, when it falls upon the wound, acts substantially like the drop. Prof. Lister's aim is to destroy the life of that floating matter—to kill such germs as it may contain. Had he, for example, dressed my wound, instead of opening it incautiously in the midst of air laden with the germs of bacteria, and instead of applying to it gold-beater's-skin, which probably carried these germs upon its surface, he would have showered upon the wound, during the time of dressing, the spray of some liquid capable of killing the germs. The liquid usually employed for this purpose is dilute carbolic acid, which, in his skilled hands, has become a specific against putrefaction and all its deadly consequences.

We now pass the bounds of surgery proper, and enter the domain of epidemic disease, including those fevers so sagaciously referred to by Boyle. The most striking analogy between a *contagium* and a ferment is to be found in the power of indefinite self-multiplication possessed and exercised by both. You know the exquisitely truthful figures regarding leaven employed in the New Testament. A particle hid in three measures of meal leavens it all. A little leaven leaveneth the whole lump. In a similar manner a particle of *contagium* spreads through the human body and may be so multiplied as to strike down whole populations. Consider the effect produced upon the system by a microscopic quantity of the virus of small-pox. That virus is to all intents and purposes a seed. It is sown as leaven is sown, it grows and multiplies as leaven grows and multiplies, and it always reproduces itself. To Pasteur we are indebted for a series of masterly researches, wherein he exposes the looseness and general baselessness of prevalent notions regarding the transmutation of one ferment into another. He guards himself against saying it is impossible. The true investigator is sparing in the use of this word, though the use of it is unsparingly ascribed to him; but, as a matter of fact, Pasteur has never been able to effect the alleged transmutation, while he has been always able to point out the open doorways through which the affirmers of such transmutations had allowed error to march in upon them.[1]

The great source of error here has been already alluded to in this discourse. The observers worked in an atmosphere charged with the germs of different organisms; the mere accident of first possession

[1] Those who wish for an illustration of the care necessary in these researches, and of the carelessness with which they have in some cases been conducted, will do well to consult the Rev. W. H. Dallinger's excellent "Notes on Heterogenesis," in the October number of the *Popular Science Review*.

rendering now one organism, now another, triumphant. In different stages, moreover, of its fermentative or putrefactive changes, the same infusion may so alter as to be successively taken possession of by different organisms. Such cases have been adduced to show that the earlier organisms must have been transformed into the later ones, whereas they are simply cases in which different germs, because of changes in the infusion, render themselves valid at different times.

By teaching us how to cultivate each ferment in its purity—in other words, by teaching us how to rear the individual organism apart from all others—Pasteur has enabled us to avoid all these errors. And where this isolation of a particular organism has been duly effected it grows and multiplies indefinitely, but no change of it into another organism is ever observed. In Pasteur's researches the Bacterium remained a Bacterium, the Vibrio a Vibrio, the Penicillium a Penicillium, and the Torula a Torula. Sow any of these in a state of purity in an appropriate liquid, you get it, and it alone, in the subsequent crop. In like manner, sow small-pox in the human body, your crop is small-pox. Sow there scarlatina, and your crop is scarlatina. Sow typhoid virus, your crop is typhoid—cholera, your crop is cholera. The disease bears as constant a relation to its contagium as the microscopic organisms just enumerated do to their germs, or indeed as a thistle does to its seed. No wonder, then, with analogies so obvious and so striking, that the conviction is spreading and growing daily in strength that reproductive parasitic life is at the root of epidemic disease—that living ferments finding lodgment in the body increase there and multiply, directly ruining the tissue on which they subsist, or destroying life indirectly by the generation of poisonous compounds within the body. This conclusion, which comes to us with a presumption almost amounting to demonstration, is clinched by the fact that virulently-infective diseases have been discovered with which living organisms are as closely and as indissolubly associated as the growth of Torula is with the fermentation of beer.

And here, if you will permit me, I would utter a word of warning to well-meaning people. We have now reached a phase of this question when it is of the very last importance that light should once for all be thrown upon the manner in which contagious and infectious diseases take root and spread. To this end the action of various ferments upon the organs and tissues of the living body must be studied; the habitat of each special organism concerned in the production of each specific disease must be determined, and the mode by which its germs are spread abroad as sources of further infection. It is only by such rigidly accurate inquiries that we can obtain final and complete mastery over these destroyers. Hence, while abhorring cruelty of all kinds, while shrinking sympathetically from all animal suffering—suffering which my own pursuits never call upon me to inflict—an unbiased survey of the field of research now open-

ing out before the physiologist causes me to conclude that no greater calamity could befall the human race than the stoppage of experimental inquiry in this direction. A lady whose philanthropy has rendered her illustrious said to me, some time ago, that science was becoming immoral; that the researches of the past, unlike those of the present, were carried on without cruelty. I replied to her that the science of Kepler and Newton, to which she referred, dealt with the laws and phenomena of inorganic Nature; but that one great advance made by modern science was in the direction of biology, or the science of life; and that in this new direction scientific inquiry, though at the outset pursued at the cost of some temporary suffering, would in the end prove a thousand times more beneficent than it had ever hitherto been. I said this because I saw that the very researches which the lady deprecated were leading us to such a knowledge of epidemic diseases as will enable us finally to sweep these scourges of the human race from the face of this fair earth.

This is a point of such special importance that I should like to bring it home to your intelligence by a single trustworthy illustration. In 1850, two distinguished French observers, MM. Davainne and Rayer, noticed, in the blood of animals which had died of the virulent disease called *splenic fever*, small microscopic organisms resembling transparent rods, but neither of them at that time attached any significance to the observation. In 1861 Pasteur published a memoir on the fermentation of butyric acid, wherein he described the organism which provoked it; and, after reading this memoir, it occurred to Davainne that splenic fever might be a case of fermentation set up within the animal body by the organisms which had been observed by him and Rayer. This idea has been placed beyond all doubt by subsequent research.

Some years in advance of the labors undertaken by Davainne, observations of the highest importance had been made on splenic fever by Pollender and Brauell. Two years ago, Dr. Burdon-Sanderson gave us a very clear account of what was known up to that time of this disorder. With regard to the permanence of the contagium, it had been proved to hang for years about localities where it had once prevailed; and this seemed to show that the rod-like organisms could not constitute the contagium, because their infective power was found to vanish in a few weeks. But other facts established an intimate connection between the organisms and the disease, so that a review of all the facts caused Dr. Sanderson to conclude that the contagium existed in two distinct forms: the one "fugitive," and visible as transparent rods; the other permanent but "latent," and not yet brought within the grasp of the microscope.

At the time that Dr. Sanderson was writing this report, a young German physician, named Koch, occupied with the duties of his profession in an obscure country district, was already at work, applying,

during his spare time, various original and ingenious devices to the investigation of splenic fever. He studied the habits of the rod-like organisms, and found the aqueous humor of an ox's eye to be particularly suitable for their nutrition. With a drop of the aqueous humor he mixed the tiniest speck of a liquid containing the rods, placed the drop under his microscope, warmed it suitably, and observed the subsequent action. During the first two hours hardly any change was noticeable; but at the end of this time the rods began to lengthen, and the action was so rapid that at the end of three or four hours they attained from ten to twenty times their original length. At the end of a few additional hours they had formed filaments in many cases a hundred times the length of the original rods. The same filament, in fact, was frequently observed to stretch through several fields of the microscope. Sometimes they lay in straight lines parallel to each other; in other cases they were bent, twisted, and coiled, into the most graceful figures; while sometimes they formed knots of such bewildering complexity that it was impossible for the eye to trace the individual filaments through the confusion.

Had the observation ended here an interesting scientific fact would have been added to our previous store, but the addition would have been of little practical value. Koch, however, continued to watch the filaments, and after a time noticed little dots appearing within them. These dots became more and more distinct, until finally the whole length of the organism was studded with minute ovoid bodies, which lay within the outer integument like peas within their shell. By-and-by the integument fell to pieces, the place of the organism being taken by a long row of seeds or spores. These observations, which were confirmed in all respects by the celebrated naturalist Cohn, of Breslau, are of the first importance. They clear up the existing perplexity regarding the latent and visible contagia of splenic fever; for, in the most conclusive manner, Koch proved the spores, as distinguished from the rods, to constitute the contagium of the fever in its most deadly and persistent form.

How did he reach this important result? Mark the answer. There was but one way open to him to test the activity of the contagium, and that was the inoculation with it of living animals. He operated upon Guinea-pigs and rabbits, but the vast majority of his experiments were made with mice. Inoculating them with the fresh blood of an animal suffering from splenic fever, they invariably died of the same disease within twenty or thirty hours after inoculation. He then sought to determine how the contagium maintained its vitality. Drying the infectious blood containing the rod-like organisms, in which, however, the spores were not developed, he found the contagium to be that which Dr. Sanderson calls "fugitive." It maintained its power of infection for five weeks at the farthest. He then dried blood containing the fully-developed spores, and exposed the sub-

stance to a variety of conditions. He permitted the dried blood to assume the form of dust; wetted this dust, allowed it to dry again, permitted it to remain for an indefinite time in the midst of putrefying matter, and subjected it to various other tests. After keeping the spore-charged blood which had been treated in this fashion for four years, he inoculated a number of mice with it, and found its action as fatal as that of blood fresh from the veins of an animal suffering from splenic fever. There was no single escape from death after inoculation by this deadly contagium. Uncounted millions of these spores are developed in the body of every animal which has died of splenic fever, and every spore of these millions is competent to produce the disease. The name of this formidable parasite is *Bacillus anthracis*.[1]

Now, the very first step toward the extirpation of these contagia is the knowledge of their nature; and the knowledge brought to us by Dr. Koch will render as certain the stamping out of splenic fever as the stoppage of the plague of *pébrine* by the researches of Pasteur. One small item of statistics will show what this implies. In the single district of Novgorod in Russia, between the years 1867 and 1870, over 56,000 cases of death by splenic fever, among horses, cows, and sheep, were recorded. But its ravages did not confine themselves to the animal world, for, during the time and in the district referred to, 528 human beings perished in the agonies of the same disease.

A description of the fever will help you to come to a right decision on the point which I wish to submit to your consideration. "An animal," says Dr. Burdon-Sanderson, "which perhaps for the previous day has declined food and shown signs of general disturbance, begins to shudder and to have twitches of the muscles of the back, and soon after becomes weak and listless. In the mean time the respiration becomes frequent and often difficult, and the temperature rises to three or four degrees above the normal; but soon convulsions, affecting chiefly the muscles of the back and loins, usher in the final collapse, of which the progress is marked by complete loss of power of moving the trunk or extremities, diminution of temperature, mucous and sanguinolent alvine evacuations, and similar discharges from the mouth and nose." In a single district of Russia, as above remarked, 56,000 horses, cows, and sheep, and 528 men and women, perished in this way during a period of two or three years. What the annual fatality is throughout Europe I have no means of knowing. Doubtless it must be very great. The question, then, which I wish to submit to your judgment is this: Is the knowledge which reveals

[1] To produce its characteristic effects the contagium of splenic fever must enter the blood. The virulently-infective spleen of a diseased animal may be eaten with impunity by mice. On the other hand, the disease refuses to be communicated by inoculation to dogs, partridges, or sparrows. In their blood *Bacillus anthracis* ceases to act as a ferment.

to us the nature, and which assures the extirpation, of a disorder so virulent and so vile, worth the price paid for it? It is exceedingly important that assemblies like the present should see clearly the issues at stake in such questions as this, and that the properly-informed common-sense of the community should temper, if not restrain, the rashness of those who, meaning to be tender, would virtually enact the most hideous cruelty by the imposition of short-sighted restrictions upon physiological investigation. It is a modern instance of zeal for God, but not according to knowledge, and an instructed public opinion must correct its excess.

And now let us cast a backward glance on the field we have traversed, and try to extract from our labors such further profit as they can yield. For more than two thousand years the attraction of light bodies by amber was the sum of human knowledge regarding electricity, and for more than two thousand years fermentation was effected without any knowledge of its cause. In science one discovery grows out of another, and cannot appear without its proper antecedent. Thus, before fermentation could be understood, the microscope had to be invented and brought to a considerable degree of perfection. Note the growth of knowledge. Leeuwenhoek, in 1680, found yeast to be a mass of floating globules, but he had no notion that the globules were alive. This was proved in 1835 by Cagniard de la Tour and Schwann. Then came the question as to the origin of such microscopic organisms, and in this connection the memoir of Pasteur, published in the "Annales de Chimie" for 1862, is epoch-making, proving as it did to all competent minds spontaneous generation to be thus far a chimera. On that investigation all Pasteur's subsequent labors were based. Ravages had over and over again occurred among French wines. There was no guarantee that they would not become acid or bitter, particularly when exported. The commerce in wines was thus restricted, and disastrous losses were often inflicted on the wine-grower. Every one of these diseases was traced to the life of an organism. Pasteur ascertained the temperature which killed these ferments of disease, proving it to be so low as to be perfectly harmless to the wine. By the simple expedient of heating the wine to a temperature of 50° centigrade, he rendered it unalterable, and thus saved his country the loss of millions. He then went on to vinegar—*vin aigre*, acid wine—which he proved to be produced by a fermentation set up by a little fungus called *Mycoderma aceti*. *Torula*, in fact, converts the grape-juice into alcohol, and *Mycoderma aceti* converts the alcohol into vinegar. Here also frequent failures occurred and severe losses were sustained. Through the operation of unknown causes, the vinegar often became unfit for use; sometimes, indeed, falling into utter putridity. It had been long known that mere exposure to the air was sufficient to destroy it. Pasteur studied all

these changes, traced them to their living causes, and showed that the permanent health of the vinegar was insured by the destruction of this life. He passed from the diseases of vinegar to the study of a malady which a dozen years ago had all but ruined the silk-husbandry of France. This malady, which received the name of *pébrine*, was the product of a parasite which first took possession of the intestinal canal of the silkworm, spread throughout its body, and filled the sack which ought to contain the viscid matter of the silk. Thus smitten, the worm would go automatically through the process of spinning when it had nothing to spin. Pasteur followed this parasitic destroyer from year to year, and, led by his singular power of combining facts with the logic of facts, discovered eventually the precise phase in the development of the insect when the disease which assailed it could with certainty be stamped out. Pasteur's devotion to this inquiry cost him dear. He restored to France her silk-husbandry, rescued thousands of her population from ruin, set the looms of Italy also to work, but emerged from his labors with one of his sides permanently paralyzed. His last investigation is embodied in a work entitled "Studies on Beer," in which he describes a method of rendering beer permanently unchangeable. That method is not so simple as those found effectual with wine and vinegar, but the principles which it involves are sure to receive extensive application at some future day. Taking into account all these labors of Pasteur, it is no exaggeration to state that the money value of his work would go far to cover the indemnity which France had to pay to Germany.

There are other reflections connected with this subject which, even were I to pass them over without remark, would sooner or later occur to every thoughtful mind in this assembly. I have spoken of the floating dust of the air, of the means of rendering it visible, and of the perfect immunity from putrefaction which accompanies the contact of moteless air. Consider the woes which this wafted matter, during historic and prehistoric ages, has inflicted on mankind; consider the loss of life in hospitals from putrefying wounds; consider the loss in places where there are plenty of wounds but no hospitals, and in the ages before hospitals were anywhere founded; consider the slaughter which has hitherto followed that of the battle-field, when those bacterial destroyers are let loose, often producing a mortality far greater than that of the battle itself; add to this the other conception that in times of epidemic disease the self-same floating matter has frequently, if not always, mingled with it the special germs which produce the epidemic, being thus enabled to sow pestilence and death over nations and continents—consider all this, and you will come with me to the conclusion that all the havoc of war, ten times multiplied, would be evanescent if compared to the ravages due to atmospheric dust.

This preventable destruction is going on to-day, and it has been permitted to go on for ages, without a whisper of information regard-

ing its cause being vouchsafed to the suffering sentient world. We have been scourged by invisible thongs, attacked from impenetrable ambuscades, and it is only to-day that the light of science is being let in upon the murderous dominion of our foes. Men of Glasgow, these facts excite in me the thought that the rule and governance of this universe are different from what we in our youth supposed them to be—that the inscrutable Power, at once terrible and beneficent, in whom we live and move and have our being and our end, is to be propitiated by means different from those usually resorted to. The first requisite toward such propitiation is *knowledge;* the second is *action*, shaped and illuminated by that knowledge. Of knowledge we already see the dawn, which will open out by-and-by to perfect day, while the action which is to follow has its unfailing source and stimulus in the moral and emotional nature of man—in his desire for personal well-being, in his sense of duty, in his compassionate sympathy with the sufferings of his fellow-men. "How often," says Dr. William Budd, in his celebrated work on "Typhoid Fever"—"how often have I seen in past days, in the single narrow chamber of the day-laborer's cottage, the father in the coffin, the mother in the sick-bed in muttering delirium, and nothing to relieve the desolation of the children but the devotion of some poor neighbor, who in too many cases paid the penalty of her kindness in becoming herself the victim of the same disorder!" From the vantage-ground already won I look forward with confident hope to the triumph of medical art over scenes of misery like that here described. The cause of the calamity being once clearly revealed, not only to the physician, but to the public, whose intelligent coöperation is absolutely essential to success, the final victory of humanity is only a question of time. We have already a foretaste of that victory in the triumphs of surgery as practised at your doors.

THE PROTECTION OF BUILDINGS FROM LIGHTNING.

By Professor J. CLERK MAXWELL.

MOST of those who have given directions for the construction of lightning-conductors have paid great attention to the upper and lower extremities of the conductor. They recommend that the upper extremity of the conductor should extend somewhat above the highest part of the building to be protected, and that it should terminate in a sharp point, and that the lower extremity should be carried as far as possible into the conducting strata of the ground, so as to "make" what telegraph engineers call "a good earth."

The electrical effect of such an arrangement is to *tap*, as it were, the gathering charge by facilitating a quiet discharge between the

atmospheric accumulation and the earth. The erection of the conductor will cause a somewhat greater number of discharges to occur at the place than would have occurred if it had not been erected; but each of these discharges will be smaller than those which would have occurred without the conductor. It is probable, also, that fewer discharges will occur in the region surrounding the conductor.

It appears to me that these arrangements are calculated rather for the benefit of the surrounding country, and for the relief of clouds laboring under an accumulation of electricity, than for the protection of the building on which the conductor is erected.

What we really wish is, to prevent the possibility of an electric discharge taking place within a certain region, say in the inside of a gunpowder-manufactory. If this is clearly laid down as our object, the method of securing it is equally clear.

An electric discharge cannot occur between two bodies, unless the difference of their potentials is sufficiently great, compared with the distance between them. If, therefore, we can keep the potentials of all bodies within a certain region equal, or nearly equal, no discharge will take place between them. We may secure this by connecting all these bodies by means of good conductors, such as copper-wire ropes, but it is not necessary to do so, for it may be shown by experiment that, if every part of the surface surrounding a certain region is at the same potential, every point within that region must be at the same potential, provided no charged body is placed within the region.

It would, therefore, be sufficient to surround our powder-mill with a conducting material, to sheathe its roof, walls, and ground-floor, with thick sheet-copper, and then no electrical effect could occur within it on account of any thunder-storm outside. There would be no need of any earth-connection. We might even place a layer of asphalt between the copper floor and the ground, so as to insulate the building. If the mill were then struck with lightning, it would remain charged for some time, and a person standing on the ground outside and touching the wall might receive a shock, but no electrical effect would be perceived inside, even on the most delicate electrometer. The potential of everything inside with respect to the earth would be suddenly raised or lowered, as the case might be, but electric potential is not a physical condition, but only a mathematical conception, so that no physical effect would be perceived.

It is, therefore, not necessary to connect large masses of metal, such as engines, tanks, etc., to the walls, if they are entirely within the building. If, however, any conductor, such as a telegraph-wire or a metallic supply-pipe for water or gas, comes into the building from without, the potential of this conductor may be different from that of the building, unless it is connected with the conducting-shell of the building. Hence the water or gas, supply-pipes, if any enter the building, must be connected to the system of lightning-conduct-

ors, and, since to connect a telegraph-wire with the conductor would render the telegraph useless, no telegraph from without should be allowed to enter a powder-mill, though there may be electric bells and other telegraphic apparatus entirely within the building.

I have supposed the powder-mill to be entirely sheathed in thick sheet-copper. This, however, is by no means necessary in order to prevent any sensible electrical effect taking place within it, supposing it struck by lightning. It is quite sufficient to inclose the building with a network of a good conducting substance. For instance, if a copper wire, say No. 4, B. W. G. (0.238 inch diameter), were carried round the foundation of the house, up each of the corners and gables and along the ridges, this would probably be a sufficient protection for an ordinary building against any thunder-storm in this climate. The copper wire may be built into the wall to prevent theft, but should be connected to any outside metal, such as lead or zinc on the roof, and to metal rain-water pipes. In the case of a powder-mill it might be advisable to make the network closer by carrying one or two additional wires over the roof and down the walls to the wire at the foundation. If there are water or gas pipes which enter the building from without, these must be connected with the system of conducting-wires, but, if there are no such metallic connections with distant points, it is not necessary to take any pains to facilitate the escape of the electricity into the earth.

Still less is it advisable to erect a tall conductor with a sharp point in order to relieve the thunder-clouds of their charge.

It is hardly necessary to add that it is not advisable, during a thunder-storm, to stand on the roof of a house so protected, or to stand on the ground outside and lean against the wall.—*Nature.*

MORMONISM FROM A MORMON POINT OF VIEW.

By DANIEL WEDDERBURN.

DURING a recent visit to Salt Lake City I happened to ask one of the leading Mormons what works, in addition to the Book of Mormon, would give me a fair idea of the religious doctrines professed by the Latter-day Saints and of their history, as they themselves desire to have it told. The gentleman addressed most kindly offered for my acceptance several books, among which were pamphlets by Orson Pratt, one of the twelve apostles of the church, the "Key to the Science of Theology," by Parley P. Pratt, and the "Rise, Progress, and Travels of the Church of Jesus Christ of Latter-day Saints," by President George A. Smith.

So far as religious tenets are concerned, the authority of the works

mentioned may doubtless be accepted as final. With regard to the historical portion of the subject it is different, and here a certain allowance must be made for the bias of a religious partisan; but it is not the less interesting to read this brief but stirring history, as it is told by those who played a prominent part in its events. Having studied these books, I shall endeavor to give a short account of Mormonism, as it is described by the Mormons themselves, and as it appears to myself, being personally little predisposed to regard it favorably, but convinced that its case has seldom been fairly stated to the public.

A certain practical importance attaches at present to the subject, for the future position of Mormonism in the Union is among the many difficult political problems now offering themselves for solution in the United States of America. It presents, indeed, upon a small scale, a similar difficulty to that caused by the existence of slavery in the Southern States: as to how far it is possible to maintain political federation between communities differing essentially in their social institutions. The American Constitution is wonderfully elastic, but it has proved impossible to retain slaveholding States permanently within its limits. Is its elasticity sufficient to admit into the Union a State which would legalize polygamy? Hitherto a negative answer has been given by Congress to this question, and the claims of Utah Territory to become a State have been urged in vain; but the steady increase of population and wealth is constantly strengthening those claims, and they cannot much longer be ignored. The fourth unsuccessful attempt to obtain admission as a State of the Union was made in 1872, when the population of Utah already exceeded that of Nevada and Nebraska combined (at the date of their admission), being upward of 105,000; and a memorial to Congress was adopted, praying for admission into the Union as a sovereign State. The constitution then proposed for the State, which was to bear the name of Deseret, was approved by the people of the Territory, with only 368 dissentient votes; it provided for women's suffrage, and minority representation.

The admission of Nevada, Nebraska, and Colorado, all of them neighboring Territories with inferior population to Utah, appears to justify the assertion of the Mormons that the unpopularity of their religion was the sole cause of their exclusion. Had Deseret been created a sovereign State in 1872, the controversy as to polygamy might have entered upon a new and critical phase, as the State Legislature would doubtless have claimed the right to legalize plurality of wives within its own jurisdiction. No such right can be claimed by the existing Legislature of Utah, whose powers are restricted by the provisions of the act of 1850, to which the Territory owes its political existence. All laws of the Territorial Legislature must have the sanction of the Governor (who is appointed by the President of the

United States), and are passed subject to the approval of Congress. The judges of the Territorial Supreme Court are also appointed by the President, so that the control of the Federal authorities is complete over all departments in the Territory, and it is natural that the Mormon community should aspire to a more independent position. It is questionable, however, whether independence would not prove a disadvantage to the Mormons, as tending to bring them into direct collision with popular feeling, which has always been more or less hostile to them throughout the Union, while the Federal authorities have acted a friendly part. During seventeen sessions of the Utah Legislative Assembly, the power of disapproval has only once been exercised by Congress, and then (as might have been expected) in relation to the law of marriage. The Washington Government has afforded protection to the Mormons against local officers and judges, President Grant, in particular, having recently braved considerable unpopularity by removing the Chief-Justice of the Supreme Court of Utah for "arbitrary and illegal conduct" in his dealings with the Latter-day Saints. Again, a few years ago the United States officials in Utah set at naught the Territorial law under which jurors were selected and summoned, rejecting those who professed their belief in Mormon doctrines. Where the value at issue exceeds $1,000, an appeal lies to the Supreme Court of the United States, and a case tried by a packed jury, and given against the municipal officers of Salt Lake City, was accordingly appealed. The unanimous decision of the Supreme Court at Washington was, that the jury had not been legally impaneled, and the judgment of the Utah court was reversed. Great rejoicing was caused at Salt Lake City by this decision in the Engelbrecht case, as proving that the inhabitants of Territories had rights in common with their countrymen, and that there was justice in the United States even for the professors of a very unpopular religion.

It may appear strange that in the freest of lands, and in the latter half of the nineteenth century, a legal doubt should have existed as to whether civil disabilities were attached to any form of religious opinion; but it must be remembered that the evidence of an atheist was very recently rejected in English courts of justice, and the Legislature of North Carolina expelled last year a member, because he conscientiously declared his disbelief in the existence of God. The fact is that, even in Protestant countries, complete religious toleration is limited to certain recognized persuasions, so that feeble and unpopular sects have still to unite in claiming for themselves the same liberty of conscience which has been conceded to all numerous and powerful dissenting bodies. Science now demands from theology absolute and unconditional freedom, and the day can hardly be far distant when theological heterodoxy will cease to involve any civil penalties in a free country. At present the Mormon refugees of the

Rocky Mountains demand only that amount of civil and religious liberty which the Constitution professes to guarantee to every American citizen, and which the Pilgrim Fathers found for themselves "on the wild New England shore." They complain that their enemies have told their story, that their own statements have been ignored, and that no credit has been given to them for an honest attempt, in these latter days, to put in practice the doctrines of the early Christian Church. Even their enemies will hardly deny that they displayed faith, courage, and endurance, when they resolved, after being expelled from one settlement after another, to plunge into the unknown wilderness, and to found a new Zion beyond the existing limits of the United States. These qualities have triumphed over great physical difficulties, and a stranger is astonished at the prosperity which Mormon industry has produced. A carefully-organized system of irrigation has converted a barren desert into a productive garden, and has had the remarkable effect of raising the permanent level of the lake ten feet higher than it was in 1850. Every requirement of the religious community is abundantly supplied by contributions, assessed and collected upon voluntary principles. Besides the immense new Tabernacle, a temple is now in course of construction, almost Egyptian in its massive grandeur, toward which all the faithful contribute, those who cannot afford money giving their labor. The Indians in Utah have been conciliated by the humane policy of feeding, clothing, and teaching, instead of fighting them. The old accusations of violence and cruelty toward Gentile immigrants, or Mormon deserters, if not altogether disproved, have at least been lived down in recent times, and the existence of a military camp near Salt Lake City is now, probably, more unnecessary than it would be at any other town west of the Rocky Mountains. In order to appreciate the tranquillity, sobriety, and steady industry of Deseret (as the Mormons prefer to name their country), it may be contrasted with Nevada, an adjoining State almost identical with Deseret as to soil, climate, and mineral products. The so-called Silver State stands now preëminent in the Union for its turbulent manners, for the number of its liquor-shops, and as being the only State which legalizes public gambling. Of course, Nevada is merely passing through a certain rude stage of her existence, just as California had done before her, and she, too, will one day set her house in order; the remarkable point is that Utah should, alone among the young communities of the far West, have altogether escaped such a condition of things. To many persons this will appear to be sufficiently explained by the fact that the Mormons both preach and practise habits of extreme temperance, almost amounting to total abstinence from every sort of stimulant.

Considerable hostility undoubtedly exists between the Mormons and some of their Gentile fellow-residents; this is greatly due to the bitter attacks of certain local newspapers upon the Latter-day Saints,

and upon those who show them any favor. When I was in Salt Lake City, the Governor of Utah Territory was very severely assailed for his alleged partiality toward the Mormons, and a grim hope was at the same time expressed that Mr. Brigham Young might shortly take the place merited by him "at the only fireside, which we know of, large enough to accommodate him and the whole of his family." That such expressions are publicly used in speaking of a man whom the great bulk of the community regard as an inspired prophet, is a sufficient proof that no terrorism is now exercised against dissenters from the dominant church of Utah. To a stranger like myself, desirous of understanding as far as possible the tenets of their faith, a frank and friendly reception was accorded by such of the Mormon leaders as I had an opportunity of visiting. Every explanation asked for was at once afforded, but I do not feel justified in mentioning names, or in repeating any private conversation, although it was probably not intended to be confidential. A passing stranger can only see the external surface of society, and in this respect there is nothing very remarkable in Salt Lake City. The parlor of a flourishing Mormon householder does not differ much in appearance from that of an Englishman who happens to have a numerous family, with a large proportion of sisters or daughters. A new and somewhat startling sensation is, however, experienced during the ceremony of introduction on first hearing the words, "Now, sir, let me introduce you to another of my wives." The strangeness of these words mainly consists in the very fact that they are uttered, not by a dark-skinned barbarian, but by a gentleman answering to the description of the English soldiers given by "Le Conscrit de 1813"—"blancs, bien rasés, comme de bons bourgeois"—and in a room with all the familiar surroundings of civilized domestic life. The public worship of the Church of Jesus Christ of Latter-day Saints, as the Mormons invariably designate their own sect, is conducted with great simplicity, very much as it is in an English dissenting chapel, and the preponderance of ladies is by no means greater than that to which we are accustomed in places of worship generally. The only marked peculiarity is the administration of the Lord's Supper in water instead of wine, and of this sacrament it appears to be customary for all the faithful present to partake, old and young alike. The hymns are sung by a mixed choir of young men and women, and addresses are delivered by eminent Mormon elders. When I was present, the speakers were Mr. Daniel H. Wells, Mayor of Salt Lake City, and Mr. Cannon, brother of the delegate from Utah Territory to Congress. All religious argument was based upon the authority of the Bible, to which the Mormon revelations claim to be *additional*, but in no sense *contrary*. Various Mormon doctrines were touched upon, and special allusions were made to the persecutions undergone by the Saints in past times, and to those which appeared to menace them in the future. Although not

yet half a century old, the Church of Jesus Christ of Latter-day Saints has passed through a baptism of fire, and living men can speak with mingled pride and sorrow of personal friends who died as martyrs to their religious faith. Thirty years ago Nauvoo, in Illinois, was a Mormon settlement, almost equal in population and prosperity to Salt Lake City at the present day; those who witnessed its total destruction can hardly be considered idle alarmists, when they allude to the possibility of trials yet to come. The tone of the speakers was thoroughly practical, exhorting to industry and sobriety, to abstention from all stimulants, including tobacco, coffee, and tea, and to the cultivation of all the useful arts, "even those of war, if necessary to the safety of our community." These exhortations were mainly addressed to the juniors present, a saving clause being inserted for those seniors who had borne the burden and heat of the evil days, and who, having now established this mountain refuge for the Saints, might require to "solace decaying nature" with an occasional narcotic. The addresses breathed a tolerant and rational spirit, the doctrines inculcated were simply those of a charitable form of Christianity, and there was no mention of that peculiar domestic institution which sums up in the minds of so many all notions connected with Mormonism.

After all, it is upon "plural marriages" that the interest as well as the hostility of the outer world has always been concentrated; a Mormon is simply regarded as a man with a number of wives, and beyond this most people know little, and care less, as to the doctrines or customs of the Latter-day Saints. Were it not for their polygamy, it seems probable that the Mormons might now enjoy the same perfect toleration which is extended in America to other forms of religious eccentricity, and that Deseret would long ere this have taken her place among the States of the Union. On the other hand, it must be borne in mind that polygamy is a comparatively recent innovation, condemned by the Book of Mormon in the strongest possible terms:

> "The word of God burdens me because of your grosser crimes. For behold, thus saith the Lord, this people (the Nephites) begin to wax in iniquity; they understand not the Scriptures; for they seek to excuse themselves because of the things which were written concerning David and Solomon his son. Behold, David and Solomon truly had many wives and concubines, which thing was abominable before me, saith the Lord; wherefore, thus saith the Lord, I have led this people forth out of the land of Jerusalem, by the power of mine arm, that I might raise up unto me a righteous branch from the fruit of the loins of Joseph. Wherefore I, the Lord God, will not suffer that this people shall do like unto them of old. Wherefore, my brethren, hear me, and hearken to the word of the Lord; for there shall not any man among you have save it be one wife, and concubines he shall have none; for I, the Lord God, delighteth (*sic*) in the chastity of women."

These are the words of "Jacob, the brother of Nephi," and words could hardly be more distinct or emphatic; but theologians can generally manage to explain away inconvenient texts and hard sayings, while in this case it may be held by the Saints that the above injunctions were repealed by the subsequent "Revelation on Celestial Marriage." This tardy revelation, vouchsafed to Joseph Smith shortly before the close of his career, is the sole warrant for plurality of wives —a practice which is general among the Mormon leaders, but not throughout the community at large. With them, as with Mohammedans or Hindoos, polygamy is doubtless very much a question of expense, and I was informed on good authority that probably about one in four of the Saints is the husband of more than one wife. The majority, therefore, adheres in practice to the "Doctrine and Covenants," which book is a recognized authority upon articles of Mormon faith, and declares that "one man should have one wife, and one woman but one husband, except in case of death, when either is at liberty to marry again." The number of wives ascribed to eminent individuals is usually exaggerated, sixteen being the largest number admittedly married to one man, and six constituting the household of a wealthy and influential elder.

The Mormons compare themselves to the Jews, as well as to the early Christians; they have been a persecuted people, driven forth to wander through trackless deserts, and are now living apart from their neighbors in a theocratic commonwealth of their own. Their precedents on behalf of polygamy are mainly drawn from the Hebrew Scriptures; but they also assert that they have in their favor the example of the primitive Christian Church. Without going into their arguments, it may be at once conceded that polygamy was sanctioned by the ancient Hebrew law; but it is not the less out of date in the new world of America, and is a standing peril to the Church of the Latter-day Saints. By an act of the Utah Legislature, the right of suffrage has been conferred on "all American women, native or naturalized," and it hardly seems possible that polygamy can long survive such legislation. At present the extension of the franchise among persons, few of whom are "native" Americans, and many of whom are very imperfectly educated, probably strengthens the hands of the Mormon leaders by swamping entirely the Gentile element. But such an effect is not likely to be permanent, for the rising generation will be educated; in 1871, just after the passing of the act above referred to, sixty per cent. of the girls between four and sixteen years of age were enrolled as scholars throughout Utah Territory, being slightly in excess of the percentage among boys of the same age. Equality between the sexes in education and in electoral privileges must tend to bring about social and religious equality also, and the example of their independent sisters in Wyoming Territory, where women enjoy complete civil rights, will not be thrown away upon the ladies of Salt

Lake City. The tone of public feeling throughout the neighboring States and Territories is more favorable toward "woman's rights" than it is in any other part of the world; and, even if this be partly due to a reaction produced by Mormonism, it cannot fail in time to influence the female electors of Utah. Thus it is possible that a peaceable solution of the difficulty may be found, and polygamy may be abolished, not by external force, but by constitutional action within the Mormon community itself.

Meanwhile, this church of the nineteenth century possesses amazing vitality, and seems to carry us back to a by-gone era of belief, exhibiting as it does the phenomenon of a religious sect heartily convinced of its future mission and claiming the present for its own. While other churches look to the past for all that is best and truest in religion, the Latter-day Saints regard the present also as a period of miracle and revelation. They expect, in the immediate future, the conversion of all who inhabit their vast continent with as serene a confidence as that with which the early Christians seem to have anticipated the evangelization of the Roman Empire. It may be said of them that in theology they maintain the modern doctrine of continuity, rather than ancient theories of convulsion and catastrophe. Accepting, in a literal sense, the Jewish and Christian Scriptures, they apparently entertain no fear lest scientific research should undermine their faith, as they look for a continuous course of revelation, which shall harmonize theology with the general advance in human knowledge.

The title of Parley P. Pratt's recent work, "Key to the Science of Theology," 1874, may seem almost to involve a contradiction in terms; but it indicates the desire of a distinguished Mormon theologian to keep abreast, if possible, of the scientific spirit of the age. Whether the attempt to do this may have proved successful or not, his policy is surely wiser than that which has frequently placed science and theology in opposition so direct, that every conquest of knowledge over ignorance has appeared to be also a victory over religion. Indeed, Mr. Parley Pratt is entitled to a welcome from the lovers of free thought, considering how rarely theologians seek to identify the progress of their own tenets with that of humanity in every department of science and art, and how seldom it is that they do not

> "Grow pale
> Lest their own judgments should become too bright,
> And their free thoughts be crimes, and earth have too much light."

To quote his own words:

"The creeds of the Fathers seem to have been cast in the mould of other ages, to be adapted to a more narrow sphere of intellectual development, and to be composed of material too much resembling cast-iron; or, at least, not sufficiently elastic to expand with the expansion of mind, to grow with the growth, and advance with the progressive principles of the age. For these reasons, per-

haps more than any other, the master-spirits of the age are breaking loose from the old moorings, and withdrawing from established and venerated systems."

Holding these views, Mr. Parley Pratt has aimed at embodying, in his introductory key, a general view of what he calls the Science of Theology, "in a concise and somewhat original manner and style, as gathered from revelation, history, prophecy, reason, and analogy." The revelation and prophecy referred to and founded upon are partly those accepted by all orthodox Christians, partly those of recent date (such as the Book of Mormon and the Doctrine and Covenants) peculiar to the followers of Joseph Smith. It is hard to reconcile polygamy with "the progressive principles of the age," and with modern ideas as to the social position and dignity of woman; but Mr. Parley Pratt is not without a scientific plea on behalf of his theological dogma. He maintains that—

"The principal object contemplated by this law is the multiplication of the children of good and worthy fathers, who will teach them the truth, and this is far preferable to sending them into the world in the lineage of an unworthy or ignorant parentage. .... A wise legislation, or the law of God, would punish with just severity the crimes of adultery or fornication, and would not suffer the idiot, the confirmed, irreclaimable drunkard, the man of hereditary disease, or of vicious habits, to possess or retain a wife; while at the same time it would provide for a good and capable man to honorably receive and entertain more wives than one. . . . The restoration of pure laws and practices has already commenced to improve or regenerate a race. A holy and temperate life; pure morals and manners; faith, hope, charity; cheerfulness, gentleness, integrity; intellectual development, pure truth, and knowledge, will produce a race more beautiful in form and features, stronger and more vigorous in constitution, happier in temperament and disposition, more intellectual, less vicious, and better prepared for long life and good days in their mortal sojourn. Each generation governed by the same laws will still improve."

This sounds plausible enough in theory, and perhaps the result of polygamy as practised in Utah is, that a large proportion of offspring is born to the most energetic, intelligent, and industrious citizens. In an age when there is reason to fear an increasing tendency to "non-survival of the fittest," such a result may be admitted as tending to counterbalance some of the disadvantages attending plurality of wives.

The highest types of domestic animals have been developed under a system of breeding and selection, very similar to that which is advocated in the above quotations, and the burden of proof seems to rest upon those who maintain that a high type of humanity cannot be developed after a similar fashion. Should the Mormons succeed in carrying out practically, for a few generations, any such ideas as are above alleged to be the main objects contemplated in their law of polygamy, they would have fair grounds for the belief that they are destined to inherit the whole earth.

A race of human beings developed (if such a thing were feasible) by strictly scientific selection and culture could not fail to gain the upper hand in the general struggle for dominion, but it remains to be seen whether any success in this direction will attend the system of the Mormons.

"Our physical organization, health, vigor, strength of body, intellectual faculties, inclinations, etc., are influenced very much by parentage. Hereditary disease, idiocy, weakness of mind or of constitution, deformity, tendency to violent and ungovernable passions, vicious appetites and desires, are engendered by parents, and are bequeathed as a heritage from generation to generation."

These are the words of a leading apologist of polygamy, who founds an argument in his own favor upon this truth, now generally admitted, but almost as generally ignored. It is impossible here to discuss so wide and so difficult a question, and I must limit myself to these few brief quotations from the "Key to the Science of Theology," leaving the reader to judge of their worth.

The series of pamphlets by Orson Pratt contains discussions on a great variety of questions connected with Mormonism. In particular the "Divine Authenticity of the Book of Mormon" is considered at great length, as well as the question, "Was Joseph Smith sent of God?"

Mr. Orson Pratt endeavors to show, in the first place, that to expect more revelation is not *unscriptural;* secondly, that it is not *unreasonable;* and, thirdly, that it is *indispensably necessary.* He then goes on to compare the evidences of the Book of Mormon and of the Bible, alleging that both alike have been confirmed by miracles, and that the prophecies of the Bible, especially those of Isaiah, have been fulfilled in the Book of Mormon and in the history of Mormonism. Throughout his elaborate arguments he assumes the genuineness and authenticity of the Bible, an assumption which he is of course entitled to make in arguing with orthodox Christians. His position is: The truth of the Bible rests upon sufficient evidence, and this evidence is in every way weaker than that which can be adduced for the Book of Mormon—therefore, *a fortiori*, the Book of Mormon is true. Whatever may be the flaw in this syllogism, those whom Archdeacon Paley satisfies cannot fail to have some trouble in disposing of Mr. Orson Pratt. Toward other Christian sects, whose creeds "are an abomination unto the Lord," the Mormon apostle displays but little brotherly feeling. Upon papist and Protestant alike he pours out the vial of his wrath and contempt in language almost too forcible for quotation; but he seeks to base every reproach directed against them upon texts from the orthodox Scriptures. The pamphlet entitled "The Bible and Tradition, without Further Revelation, an Insufficient Guide," is, in fact, a powerful onslaught upon modern Christendom, perhaps as damaging as any that a professed unbeliever could

have made, although in this case the assailant accepts with reverence the Christian Scriptures, seeking to found thereon a revelation newer and more complete.

It is somewhat disappointing, if the Book of Mormon is to be accepted as the new revelation, to find it so very inferior, alike in matter and in style, to its great predecessors. Nearly equal in bulk to the Old Testament, it lacks altogether the poetic grandeur and the graphic force of the Hebrew Scriptures, although the Biblical phraseology has been laboriously imitated throughout. It is styled "An Account written by the Hand of Mormon upon Plates taken from the Plates of Nephi. Translated by Joseph Smith, Jr.:"

> "Wherefore it is an abridgment of the record of the people of Nephi, and also of the Lamanites; written to the Lamanites, who are a remnant of the house of Israel; and also to Jew and Gentile; written by way of commandment, and also by the spirit of prophecy and of revelation. Written and sealed up, and hid up unto the Lord, that they might not be destroyed; to come forth by the gift and power of God unto the interpretation thereof: sealed by the hand of Moroni, and hid up unto the Lord, to come forth in due time by the hand of Gentile; the interpretation thereof by the gift of God.
>
> "An abridgment taken from the Book of Ether also; which is a record of the people of Jared; who were scattered at the time the Lord confounded the language of the people when they were building a tower to get to heaven; which is to show unto the remnant of the house of Israel what great things the Lord hath done for their fathers; and that they may know the covenants of the Lord, that they are not cast off forever; and also to the convincing of the Jew and Gentile, that Jesus is the Christ, the Eternal God, manifesting himself unto all nations. And now if there are faults, they are the mistakes of men; wherefore condemn not the things of God, that ye may be found spotless at the judgment-seat of Christ."

The sacred volume is divided into thirteen books, bearing the names of various prophets, one of whom is Mormon. The last book is that of Moroni, who says:

> "Behold I, Moroni, do finish the record of my father, Mormon. Behold, I have but few things to write, which things I have been commanded by my father. And now it came to pass that, after the great and tremendous battle at Cumorah, behold, the Nephites, who had escaped into the country southward, were hunted by the Lamanites, until they were all destroyed; and my father also was killed by them, and I even remained alone to write the sad tale of the destruction of my people. But, behold, they are gone, and I fulfill the commandment of my father. And whether they will slay me, I know not; therefore I will write and hide up the records in the earth, and whither I go it mattereth not. Behold my father hath made this record, and he hath written the intent thereof. And behold, I would write it also, if I had room upon the plates; but I have not; and ore I have none, for I am alone; my father hath been slain in battle, and all my kinsfolks, and I have not friends, nor whither to go; and how long the Lord will suffer that I may live I know not. Behold, four hundred years have passed away since the coming of our Lord and Saviour.
>
> "And now, behold, we have written this record according to our knowledge

in the characters which are called among us the reformed Egyptian, being handed down and altered by us, according to our manner of speech. And if our plates had been sufficiently large, we should have written in Hebrew; but the Hebrew hath been altered by us also; and if we could have written in Hebrew, behold, ye would have had no imperfection in our record. But the Lord knoweth the things which we have written, and also that none other people knoweth our language, therefore he hath prepared means for the interpretation thereof. And these things are written, that we may rid our garments of the blood of our brethren, who have dwindled in unbelief. And behold, these things which we have desired concerning our brethren, yea, even their restoration to the knowledge of Christ, is according to the prayers of all the saints who have dwelt in the land. And may the Lord Jesus Christ grant that their prayers may be answered according to their faith; and may God the Father remember the covenant which he hath made with the house of Israel; and may he bless them forever, through faith on the name of Jesus Christ! Amen."

The record in question professes to contain a history of the American Continent from the date of its first colonization by Jared and his brother at the time of the dispersion from Babel down to the year A. D. 420, when Moroni, the last of the Nephite prophets, buried his plates in the hill of Cumorah. This account of prehistoric America is but a tedious composition, full of battles and slaughter, full of proper names, of reiterations, and of unnecessary phrases. We are told how the Jaredites, emigrants from the valley of Nimrod, who "did carry with them Deseret, which by interpretation is a honey-bee," attained to great civilization and prosperity in North America, and were utterly destroyed by internecine warfare about the year 600 B. C. They were succeeded by a "remnant of the house of Joseph," brought from Jerusalem in the reign of Zedekiah to inherit the land. These appear to have crossed the Pacific Ocean, landing on the west coast of South America, whence they eventually overspread that continent. They separated before long into two distinct nations, known as Nephites and Lamanites, the former migrating from the persecutions of the latter, and sailing "forth into the west sea by the narrow neck which led into the land northward." Through the personal ministry of Jesus Christ, who visited them shortly after his ascension, the Nephites were converted from the Mosaic to the Christian faith, which was in time accepted by the Lamanites also; and for two hundred years they prospered and multiplied, and there was no contention in the land, all things being common among them. This golden age was succeeded by a period of apostasy; "and from that time forth they did have their goods and their substance no more common among them, and they began to be divided into classes, and they began to build up churches unto themselves, to get gain, and began to deny the true church of Christ." A terrible war broke out between the Nephites, now settled in North America (known as the land Desolation), and the Lamanites, who invaded them from the land Bountiful,

lying southward of the Isthmus of Darien. This war ended in the annihilation of the Nephites, "an exceeding fair and delightsome people," while a degraded remnant of the Lamanites still survive, after fifteen centuries of rapine and discord, under the name of American Indians. "Now the heads of the Lamanites were shorn; and they were naked, save it were skin, which was girded about their loins; and the skins of the Lamanites were dark, according to the mark which was set upon their fathers, which was a curse upon them because of their transgression." Thus the term *Gentile* is properly used to denote the *white man*, as distinguished from the copper-colored house of Israel, and the Mormons themselves are expressly described as the "Gentile Saints." For the remnant of Joseph a glorious future is prophesied. They, the despised redskins, shall have the land for their inheritance, and it shall be "a land of liberty unto the Gentiles, and there shall be no kings upon the land." They are to be the chief agents in building the New Jerusalem, and will be converted and redeemed before their brethren of Judah.

The story of the plates, from which the sacred book is said to have been translated, first into English, and subsequently into nearly all the European languages, is of some interest from an archæological point of view, and may be told in a few words. They are described as having been found by Joseph Smith in a cyst composed of six stones, smooth on the inner surfaces, and firmly cemented together. This stone box was buried in the side of a hill near Palmyra, in the State of New York. The plates had the appearance of gold, were six by eight inches in width and length, each plate being nearly as thick as common tin. They were filled on both sides with small characters beautifully engraved, and were fastened at one edge with three rings running through the whole: thus bound together they formed a volume about six inches in thickness, a part of which was sealed. Various unsuccessful attempts were made by the enemies of Joseph Smith to obtain possession of these plates, and they finally disappeared, having been examined and described by eleven persons, whose testimony, signed with their names, is added to the Book of Mormon.

The evidence of these persons would have been more conclusive had not all of them been believers in the new prophet; moreover, the disappearance of the plates is not quite satisfactorily explained by the statement that they were restored to the charge of the angel under whose guidance they were discovered. Still the actual existence, as well as the genuine antiquity, of plates such as Joseph Smith is said to have brought to light in 1827, seems to have been sufficiently verified elsewhere.

In 1843, near Kinderhook, Illinois, in excavating a large mound, six brass plates were discovered, of a bell-shape, four inches in length, and covered with ancient characters. They were fastened together

with two iron wires, almost entirely corroded, and were found, along with charcoal, ashes, and human bones, more than twelve feet below the surface of a mound of the sugar-loaf form common in the Mississippi Valley. Large trees growing upon these artificial mounds attest their great antiquity, and doubtless they contain much that will reward future investigation. No key has yet been discovered for the interpretation of the engravings upon these brass plates, or of the strange glyphs upon the ruins of Otolum, in Mexico; but when an amount of talent, learning, and labor, equal to that bestowed upon Egyptian hieroglyphics or Assyrian cuneiform characters, has been devoted to American antiquities, we may hope to learn something of those mysterious races whose history the Book of Mormon professes to tell.

But if we admit that the plates themselves may have been genuine, our faith in the founder of Mormonism, as a sincere religious enthusiast, is staggered by his mode of interpreting their contents. He tells us that he found along with the records an instrument, called by him the Urim and Thummim, and described as consisting of "two transparent stones set in the rim of a bow." Through the medium of this instrument, he says that he translated the unsealed portion of these scanty records, the result being a bulky volume in English, but he does not explain whether he used it as a magnifier, nor how it proved to be a Rosetta stone for his hieroglyphics, merely asserting that it was "by the gift and power of God." That Joseph Smith believed in his own mission, his character and career alike appear to indicate, and the many ecstatic visions which he describes were probably real enough to him, but the compilation of the Book of Mormon was an act involving much time and labor, and cannot be accounted for by ecstasy.

In these days of La-Salette and Paray-le-Monial it is, perhaps, too much to say that a miracle, in order to find acceptance among educated persons, must be relegated to a remote age and country, and must be invested with a certain amount of external dignity. It is, however, a severe test of faith to be called upon to accept miracles and revelations from a prophet well known to men yet living as "Joe Smith," and referred to as "Mr. S." in the writings of so eminent a disciple as Mr. Orson Pratt. A most remarkable man Mr. S. undoubtedly was, capable of inspiring alike *inestinguibil odio, ed indomato amor.* The bitter hostility of his opponents was more than equaled by the devoted zeal of his converts, and, although murdered by mob violence at the early age of thirty-eight, he had already so well accomplished his work that the new creed, instead of dying with him, continued to spread with increasing rapidity, and was preached by his apostles and elders in every quarter of the globe. He was a New-Englander, born A. D. 1805, in the State of Vermont, and began to have visions when he was about fourteen years of age. In 1830

the Church of Jesus Christ of Latter-day Saints was first organized at Fayette, in the State of New York, and its headquarters were moved gradually westward, until a considerable settlement was formed in Jackson County, Missouri. Here it was expected that the New Jerusalem would be built, but an organized system of persecution drove the Saints out of the State of Missouri, and in 1839 they took refuge in Illinois, where they built the city of Nauvoo, in Hancock County, on the banks of the Mississippi, and enjoyed a short respite from persecution. But in 1844 popular hostility broke out with increased violence, and Joseph Smith (who had been frequently brought before judicial tribunals, and invariably acquitted) proceeded with his brother Hyrum to Carthage, where they surrendered themselves prisoners on a charge of treason, the Governor of Illinois having promised them protection and a fair trial. On the 27th of June, 1844, a large body of men, with their faces blackened, surrounded the prison, and murdered the two brothers Smith. Several of these men were indicted for murder, and were tried about a year later, but they were acquitted. The persecution of the Mormons did not slacken after the death of their prophet, and in September, 1845, an armed mob commenced burning houses in Hancock County, while the authorities declared that the State was unable to protect the Mormons, and they must therefore go. Preparations were made by Brigham Young, President of the Twelve Apostles, and the other leaders of the church, to explore the Rocky Mountains in accordance with an expressed intention of the deceased prophet, and in February, 1846, the exodus of the Mormons commenced. It was not, however, rapid enough to satisfy their enemies, and in September the city of Nauvoo was burned by an armed mob, after several days' siege, and the remnant of the Mormons was driven across the Mississippi into Iowa. In the spring of 1847 Brigham Young, with a party of pioneers, started from his winter-quarters on the Missouri in search of a place of settlement. On the 24th of July he reached the Great Salt Lake Valley, after a laborious march of more than one thousand miles through an unexplored country. After erecting a fort, and hoisting the stars and stripes upon what was then Mexican territory, President Young hastened back to the banks of the Missouri, and in the fall of 1848 he arrived once more in Salt Lake Valley, with eight hundred wagons, and the main body of the Mormons. The severest hardships were undergone by these people, not only during their march, but during the first two years after settling in this barren valley, four thousand three hundred feet above the sea, but strict discipline was enforced in the camp, and a careful system of rationing was maintained, until an abundant harvest at last put an end to the necessity. In 1850 the Territorial government of Utah was organized by act of Congress, and Brigham Young was appointed Governor by the President of the United States. From that time forward the

new colony has continued to prosper and progress with almost unexampled rapidity, in spite of great disadvantages as to soil, climate, and situation.

There are few countries on the face of the globe where the Latter-day Saints have not attempted to preach their gospel, but as a rule their preaching has not been tolerated. The records of their missionary efforts make it obvious enough why they obtain so large a proportion of their converts from Great Britain and Denmark, while so few come from the Roman Catholic countries of Europe; except in Scandinavia and the British Empire, the foreign missions of the Mormons have failed through the opposition of the powers that be, who have not only prohibited the missionaries from preaching, but in many cases have expelled them from the country. Even in Norway, so bitterly hostile were the ecclesiastics as to decide that the Church of Jesus Christ of Latter-day Saints is not a *Christian* sect, in order to deprive it of the protection guaranteed by Norwegian law to all Christian dissenters. Three paragraphs from the Mormon Creed, as stated by Joseph Smith himself, will show the injustice of such a decision:

> "We believe in God, the Eternal Father, and in His Son, Jesus Christ, and in the Holy Ghost. We believe that through the atonement of Christ all mankind may be saved by obedience to the laws and ordinances of the Gospel. We believe that these ordinances are: First, Faith in the Lord Jesus Christ; second, Repentance; third, Baptism by immersion for the remission of sins; fourth, Laying on of hands for the Gift of the Holy Ghost."

It is supposed that a larger percentage of the Danes than of any other nation has hitherto embraced Mormonism, and a Danish newspaper is regularly published at Salt Lake City. Since the separation of Schleswig-Holstein from Denmark, the recruiting-ground of the Mormons has been reduced, as their preaching has been rigidly suppressed in those duchies. Of late years the immigration into Utah from the European missions has varied from one to four thousand persons annually. The most active attempts at propagandism appear to have been made about the years 1852–'53, but in this country a Mormon mission was founded as early as 1837, six years before the "Revelation on Celestial Marriage" had given its peculiar character to Mormonism.

It was not until 1843, thirteen years subsequent to the publication of the Book of Mormon, and to the first organization of the Church of Latter-day Saints, that Joseph Smith proclaimed this new and startling revelation. The style of the document resembles that of the Book of Mormon, but it reveals "a new and an everlasting covenant," distinctly at variance with the teachings of that book already quoted, and justifies the patriarchs, and David and Solomon, "as touching the principle and doctrine of their having many wives." It is addressed

to "my servant Joseph," and confers upon him "the keys and power of the priesthood: And verily, verily I say unto you, that whatsoever you seal on earth, shall be sealed in heaven." Upon "mine handmaid, Emma Smith, your wife," on the other hand, obedience and submission are inculcated in the strongest terms. She is required to "receive all those that have been given unto my servant Joseph—And I command mine handmaid, Emma Smith, to abide and cleave unto my servant Joseph, and to none else. But if she will not abide this commandment she shall be destroyed, saith the Lord." The revelation contains twenty-five short paragraphs only; it is somewhat apologetic in general tone, and is full of scriptural quotations and precedents. A considerate stipulation is made for the consent of the first bride, when another is to be espoused: "As pertaining to the law of the priesthood: If any man espouse a virgin, and desire to espouse another, and the first give her consent; and if he espouse the second, and they are virgins, and have vowed to no other man, then is he justified." A marriage contracted under the new covenant, and sealed by the appointed authority, is valid to all eternity, whereas in the case of ordinary married persons death terminates the contract, and for them in heaven there will be neither marrying nor giving in marriage.

Such are the terms of Joseph Smith's "Revelation of Celestial Marriage," which reminds one of the convenient doctrines from time to time revealed to Mohammed upon analogous subjects. One more revelation and prophecy remains to be noticed; it is said to have appeared in the "Pearl of Great Price," published at Liverpool in 1851, and to have been "given by the prophet, seer, and revelator, Joseph Smith," on Christmas-day, 1832. The date of publication is the point requiring verification, and a genuine copy of the pamphlet above named would be invaluable, as the language of the alleged prophecy has no prophetic ambiguity, and the fulfillment has been complete. In a few terse words are described the rebellion of South Carolina, and the consequent civil war, the appeal of the Southern States to Great Britain for aid, the arming of the slaves against their masters, and the outbreak of hostilities with the Indians. If there is any accuracy in the dates as stated, Joseph Smith must have been a man of rare political sagacity and foresight.

At the present day most of our religious creeds and systems resemble the great ecclesiastical edifices of the middle ages; relics of days when faith was stronger and zeal was warmer. These magnificent relics may indeed be renovated by modern hands, and upon a humble scale they can be reproduced, but the power of originating such buildings has passed away, and ecclesiastical architecture is no longer a living art. So is it with the chief accepted systems of religion; they have come down to us in their existing form from periods with which we have nothing else in common; they are not in harmony

with the tone of modern life and thought, and could not have been established in modern times. Nevertheless, they stand firmly on their ancient foundations, and will long continue to stand, more or less altered and repaired in accordance with modern exigencies.

But the Mormon church is an exception; it has been founded in these latter days, and may be said to have introduced a new order of ecclesiastical architecture, although ancient materials have been largely employed. Hence the doctrines and history of this church appear to deserve careful study, for it presents to us a living example of what its mightier predecessors must have been in their early career. The extinct dinornis may be studied in the existing apteryx, and thus (borrowing a fresh metaphor) among the fossils of the past we seem to find one recent specimen, still full of organic life, illustrating the laws of growth, the habits, and the constitution of those species whose dry bones alone remain to us now. The living apteryx seems to be doomed ere long to become like its fossil congeners; if so, the time for study and observation is short.

Even those who have least sympathy with the peculiar doctrines of the Mormons may be willing to enter a protest in their favor, when the issue really lies between religious liberty and persecution. They are the only Christian sect that has suffered in our own days severe persecution at the hands of professing Christians, and their cause on that account demands especial sympathy from all who advocate absolute religious toleration.—*Fortnightly Review.*

MORE CONCERNING MECHANICAL TOOLS.[1]

By Rev. ARTHUR RIGG, M. A.

CUTTING edges are sometimes doubled, and thus the chisel passes into another group of tools—shears. The most common of these is the ordinary household scissors opened and closed by hand; when required for heavier work, then one handle is fixed in a vise, and both hands can be employed upon the other lengthened arm (*see* Figs. 1 and 2). At other times this double chisel opens with a spring, and then the workman only employs himself in closing such upon their work (Fig. 3). Compound lever power is sometimes introduced, and, as an example of this, here is a pair of very light shears called the "little giant" (Fig. 4), the mechanical contrivances in which are so adjusted that we can, smoothly and without jar, cut an iron rod one inch wide by one-quarter inch thick. The lightness of the tool and the ease in cutting are very noticeable. It is an American con-

[1] From a lecture delivered before the London Society of Arts.

trivance, and the bar of iron is cut with the same ease as though it were of lead. This results to some extent from both jaws approaching each other. The arrangement of levers, cams, and stays, is worthy of examination after the lecture.

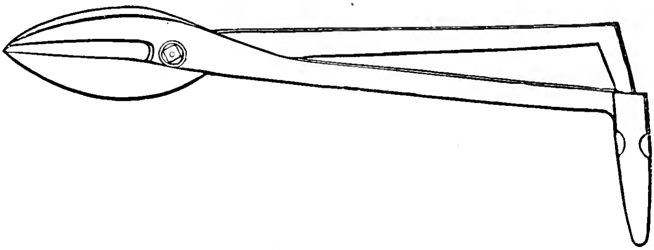


FIG. 1.

The use of the chisel, however skillfully handled, is not satisfactory over a surface wider than itself, although widened and made two-handed, as Fig. 5, and although the gouge has succeeded, or rather been planned to precede it, there is still a tendency almost unconquerable for the tool to follow the leadings of the fibres rather than cut through them at a very slight obliquity.

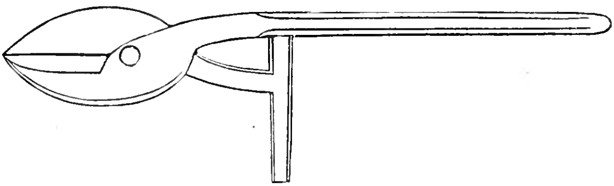


FIG. 2.

The only guidance either the axe, the adze, the pick, the gouge, or the chisel receives, is from the skill of the workman. Hence these tools produce such different work in different hands. However much it may be desirable to encourage skill in the workman, it is quite as desirable to furnish him with implements which shall make the least

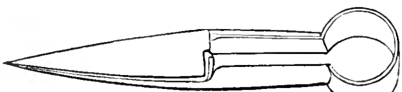


FIG. 3.

demand upon the exercise of this skill—which shall, in fact, so assist the skill in one or more directions as to permit all its care in some other direction. The assistance which the chisel needs is such as shall not only prevent it running deeper into the timber than is de-

sired, but shall enable it to be used with equal facility upon a broad as upon a narrow surface.

Given a rough piece of timber, nine inches wide and five feet long, to be smoothed by tools guided only by the handicraft skill of the workman, setting aside the adze as dangerous and unsuitable, the

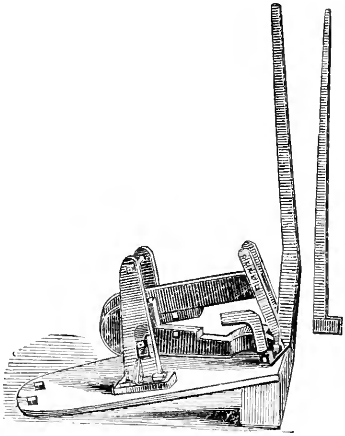


FIG. 4.

probability is, that the tools selected would be gouges and chisels of various breadths and curvatures. The order of use would probably be, first, the narrow and deeply-curved gouges, , these to be followed by the shallower and broader, A B, these again to be followed by the chisels, using in the first place a chisel wider than A B.

Let us consider what these tools would respectively accomplish if the timber is rough, as from the axe or pit-saw. The small gouge would corrugate the surface, ; the second gouge would enlarge the corrugation to this, ; and the chisel might render

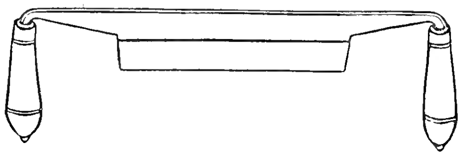


FIG. 5.

these more irregular. Such considerations as these, combined doubtless with others, led to the designing of what may be generally called the "guide principle," and this has been extended to various branches of artisan labor. At present we are only concerned with the application of this principle to gouges and chisels. This guide principle may consist of a guide as to the depth of cut, or as to the form of the

surface, or as to the direction of travel, or as to the correction of cross or longitudinal irregularities of surface.

The guide as to depth of cut is that which probably first presented itself as an important appendage to a chisel, and it has led to a form of tool of a very useful construction, although of limited range. The instrument is called a "spoke-shave." In this case the tool is that in Fig. 5 with the guide principle introduced, the depth of cut being determined by the nearness of the edge to a parallel wooden handle.

This tool, owing to the position of the application of the power, viz., the hands, and the tendency of resistance by the work to turn the whole tool in the hand, is not of general use; where, however, the curvature of surface varies, the parings to be removed are light, and the workman can have convenient access, the tool is one capable of doing good work, and, in some respects, possesses advantages over the plane, to which it probably formed an introduction.

The plane, in its most simple form, consists of a chisel inserted at an angle into a box, generally of wood, and with the cutting edge of the chisel projecting through the bottom of the box. If the actions of a workman be noted as he is smoothing wood with a chisel alone, it will be seen that he holds the bevel edge on the wood, and so elevates or lowers the handle as to secure a proper and efficient cut. Then he advances the tool in a line at right angles to its cross-section. If, now, instead of thus continuing to hold the tool, the chisel was so fixed in a movable piece of wood as to be at the same angle as the workman required, then, if the mouth were broad enough, and the instrument were propelled along the wood, a shaving would be removed very nearly the same as that obtained from the chisel alone.

In the arrangement thus sketched the workman would be relieved from the care needed to keep the tool at a constant angle with the surface of the timber. There is, however, a fixity of tool here, and consequently an optional or needful adjustment called for by any varying condition of the problem cannot be had. When operated upon by hand alone, if an obstacle to the progress of the tool is presented, as, for instance, a twist or curl in the fibre or grain of the plank—the presence of a knot—then the workman by hand can adjust the handle, and so vary the inclination of the cutting edge as the circumstances of the case require. Not so if the tool is securely fixed in a box as described.

While, therefore, one gain has been had, one loss has been encountered. Can the gain be made to more than counterbalance the loss? This can only be answered by observing the defects of the primitive plane, as hitherto described, and noting what hopeful elements it contains.

The front of the sole of the box will clearly prevent the penetration of the incased chisel into the wood, because it cannot now be

drawn to follow the fibre, should it lead inward. Suppose, however, that in the progress of the work such a place has been reached as would have so drawn the chisel inward. What will happen? Either the strength of the indrawing fibre will be so great that the workman will be unable to propel the tool, or, if not thus impeded, he must by extra effort separate the fibre and so release the tool. This separation, however, will not be by the process of cutting, but by that of tearing, and shavings so torn off will have left their marks in the roughnesses which attend the tearing asunder of fibrous woods. Thus the tool will defeat the very object for which it was designed.

Now, what is it which so forcibly draws, or tends to draw, the tool downward below the surface of the timber? The forces in operation are the hand of the workman and the tenacity of the fibre. If the tenacity is greater than the power, the workman must stop. That the tool cannot follow the direction of the fibre is clear, because the front part of the wooden sole forbids the penetration; but that it may be brought to a standstill, or must tear off the fibre, is also very clear. The mechanician has therefore to consider how to defeat these tendencies, which, as now sketched, result from a collision between the indrawing strength of the fibre and the power of the man to cross-cut the fibre by the tool, or else to tear it asunder and leave the surface rough.

Since the tool, as now contrived, cannot efficiently cross-cut the resisting fibre, and since that fibre has to be removed, the object must be either to prevent such an accumulation of fibres as will stop the progress of the tool, or to destroy the fibre piecemeal as it is operative for hinderance. Both plans have been adopted. A consideration of the former may prove introductory to the latter, which appears in almost all attempts to perfect this tool and its appended contrivance.

As the tool progresses, and the fibres become more and more impeding, it will be clear that a portion of this impediment results from a condensation of the fibre in the mouth of the wooden box. The more numerous the fibres admitted here, the greater will be the condensation. This state of affairs can be partially obviated by a narrowing of the mouth of the plane; such an act, of course, requires that the introduced chisel should enter less deeply into the timber being operated upon. Although thus abated, the cause is not removed, and even if so far abated as to prove no real impediment to the workman, yet the quantity of material removed on each occasion will be so small that the tool becomes one for finishing work only, and not for those various operations to which its present powers enable artisans to apply it.

To be the useful tool it is, the mouth must not be so narrowed, nor the inserted chisel so withdrawn, that the shaving is thus the thinnest

possible. This led to a contrivance now almost universal, that of breaking the fibre so soon as it is separated from the piece of timber. The designer seems to have considered that, as soon as a short length of shaving had been removed, it would be well to destroy the continuity of the fibre, and so prevent an accumulative resistance from this cause. Hence, instead of allowing the cut-off fibres to slide up the inserted chisel, he bent them forward, in fact, cracked them, and so broke the cumulative indrawing force of them. This he accomplished by the use of what is now called the back-iron, and henceforth the boxed-in chisel loses its identity, and must be regarded as part of an independent tool.

The tool thus built up is called a plane, and from its general utility, and capability of adaptation to various forms and conditions, it is well deserving of the high opinions entertained of its powers. Three forms of this tool are in general use in English workshops, called the "jack," the "trying," and the "smoothing" planes. These are on the bench of all workers in smooth, straight-surface wood. Although externally alike except in size, they are yet used for different purposes, and each has a specialty met with in its construction. These specialties may now be considered.

After the wood has passed from the sawyer into the hands of the carpenter, the surface undergoes those operations which render it true and smooth. These three planes do this work. The "jack," usually about fifteen inches long, and the "trying" plane, ranging from eighteen inches to twenty-four inches long, but, in exceptional cases, far exceeding these dimensions, are to external appearances alike; indeed, some regard the different handles as the only distinctions between them, and that these handles show which must be used for rough work and which for smooth (*see* Fig. 8 as an example of the handle of a "jack-plane," and Fig. 9 as an example of a "trying-plane handle"). This is an error. There are other differences, but the main and leading one is the different form given to the edge of the cutting-iron.

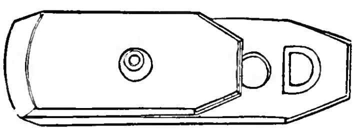


Fig. 6.

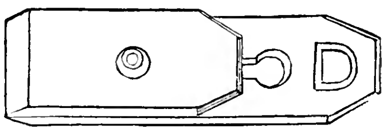


Fig. 7.

If the iron of the "jack" plane be looked at from the front end of the plane, the form of the edge will be curved, as in Fig. 6; but the iron of the "trying" plane is straight, as in Fig. 7. Upon the curvature of the edge depends the efficient action of the "jack."

Sufficient has been said of the tendency of the fibre to draw the tool downward; but it must not be forgotten that the same adhesion

of fibre to fibre takes place between the surface-fibres as among those below the surface. If tools excluded from this course of lectures had entered, we should have found that these connecting surface-fibres are separated by the addition of certain supplementary appendages to the tools. The depth to which the plane penetrates has led to the combination in one edge of such supplementary parts.

For the purpose of separating the surface connecting fibres, the jack-iron is convex. Note now its action. The convex sharp edge is pushed along an horizontal plank, penetrating to a depth determined by the projection of each vertical section below the sole of the plane. The ends of this convex edge are actually within the box of the plane; consequently (sideways) all the fibres are separated by cutting, and are therefore smooth and not torn. The effect of this upon the entire surface is to change the surface from the original section to a section irregularly corrugated. The surface after using the "jack" is ploughed, as it were, with a series of valleys and separating hillocks, the valleys being arcs from the convexity of the tool, and the separating hillocks being the intersections of these arcs. All traces of the tearing action of the saw have been removed, and from a roughened but level surface a change has been made to a smooth but in cross-section an undulating one.

The mechanician's next object is to remove these lines of separation between the valleys. For this, the trying-plane is required. The

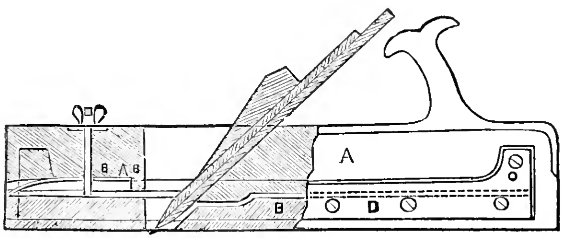


Fig. 8.

trying-plane is longer than the jack, because the sole of the plane which is level is, so far as its size goes, the counterpart of that which the surface of the wood is to be; further, the trying-plane should be broader than the jack, because its object is to remove the valleys, and not to interfere with the wood below the bottoms of the valleys. If its action passes below the bottoms of the furrows, then occasion arises for cutting the side-connection of the fibres, and, however a workman may sharpen the edge of his trying-plane for this purpose, he in one respect has destroyed one object of the plane, because, so soon as the iron penetrates below the surface, so soon does the effect of the jack-action begin to reappear, and the cutting edge should pass from the shape shown in Fig. 8 to the shape in Fig. 7. The result of

the trying-plane following the jack is to remove all the elevations of wood above the valleys the jack left; and, secondly, to compensate by its great length for any want of lineal truth consequent upon the depth of bite of the jack. Again, the mouth of the trying-plane is much narrower than that of the jack; hence the shavings removed are finer; therefore the slope of the iron, or its inclination to the wood, may be less than is the iron of the "jack"—hence the line of cut is more nearly accordant with that of the fibre, and by so much the surface is left more smooth from the trying-plane than from the jack, as there is more cutting and less tearing action than in the jack. The reasoning hitherto pursued in reference to the purpose of this sequence of a jack and trying plane might and does legitimately produce the conclusion that, after the trying-plane has done its duty, the work is as perfectly finished as it can be. Custom, and perhaps other considerations, have established that after the long trying-plane must follow the short and almost single-handed smoothing-plane. So far as the form of the iron of the smoothing-plane is concerned, there is no difference between it and the one used in the trying-plane; each (as across the plane) is straight, the corners being very slightly curved, but only so much as to insure that they do not project below the line of the cutting edge.

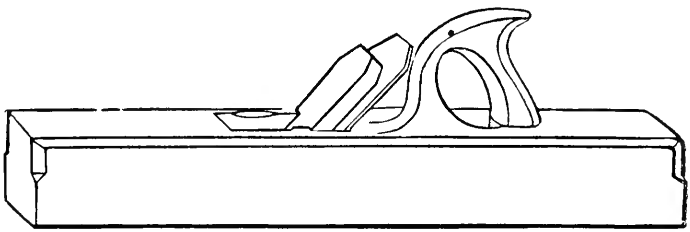


Fig. 9.

The facet edge and inclination of the cutter to the work, and the position of the back-iron, are now under consideration.

It would seem that, while the trying-plane leveled down all the elevations left by the jack, and brought the surface of the wood as a counterpart of that of the plane, there might be, in the fibre or grain of the wood, twists, curls, and other irregularities, which, while leveled, were yet left rough in consequence of the direction in which the cutting edge came upon them. Indeed, this cutting edge in a long plane, which must advance in the direction of its length, must at times come across a large number of surfaces where the fibre is in opposite directions. The consequence is, that there will be various degrees of smoothness; for good work these must be brought to uniformity. This is effected by passing a short-soled plane over the respective parts of the surface in such directions as observation may suggest. Hence the smoothing-plane is of use chiefly to compensate for such

changes in the direction of the fibres of the wood as the longer length of the trying-plane could not conveniently deal with. Hitherto, we have regarded the plane as arranged with a "guide principle" which shall always repeat a straight, level surface. The guide may, however, be the counterpart of any required surface. The plane made of iron, now in my hand, has an elastic steel sole, which, by means of adjusting screws, enables a workman readily to convert a straight-faced sole into one either concave or convex. This is an American production (*see* Fig. 10).

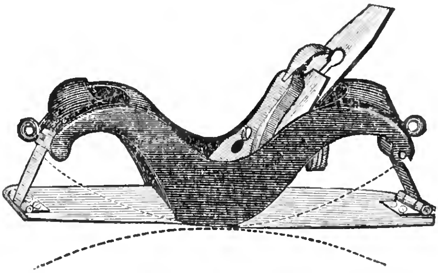


FIG. 10.

There is also in this and other planes a mode of fixing the iron which deserves more general adoption than it receives, viz., by a cam-action. It will often be noticed that, where the holding-wedge binds on the box of the plane in our ordinary planes, the wood has split. This arises from a commendable but, in this case, too strict a care for a good fit; hence the wedge is made tight where it should be slack.

WHAT AMERICAN ZOÖLOGISTS HAVE DONE FOR EVOLUTION.[1]

BY PROFESSOR EDWARD S. MORSE.

II.

IN the "Memoirs of the American Academy of Sciences" may be found a profound mathematical essay "On the Uses and Origin of the Arrangement of Leaves and Plants,"[2] by the lamented Chauncey Wright. After discussing the laws of phyllotaxy, and showing that the botanist is wrong in supposing this a law at the outset, Mr. Wright states "one of the utilities, so to speak, in the apparently

[1] An address delivered at the meeting of the American Association for the Advancement of Science. Read at Buffalo, New York, August, 1876, by Edward S. Morse, Vice-President of Biological Section.

[2] "Memoirs of the American Academy," vol. ix., p. 379.

undeviating arrangement of leaves, to be the distributing of leaves most rapidly and thoroughly around the stem, exposed more completely to light and air, and provided with greater freedom for symmetrical expansion, together with more compact arrangement of bud;" and he asks, "What has determined such an arrangement of vital forces?" Theory of types would say, their very nature, or an ultimate creative power. Theory of adaptation would say, the necessity of their lives, both outward and inward; or the conditions, both past and present, of their existence.

Whatever tends to show modification in the markings, color, size, food, or change in the variety of habits manifested by animals, furnishes just so many indications of the unstable character of what had before been considered stable, and gives an infinitely wider field for those unconscious selections whose operations are coincident with every change in the physical features of the earth. On the theory of derivation additional confirmation is given to the deductions of geologists based upon the stratigraphical and paleontological evidences of the rocks. The survival of a marine crustacean in the deeper waters of Lake Michigan, as discovered by Stimpson, coupled with similar occurrences in the lakes of Sweden, suggests the past connection of these waters with the ocean. In the same way the persistence of arctic forms on high mountain-tops indicates the existence in past times of wide-spread glacial fields. The interesting discoveries of Mr. Ernest Ingersoll, in the Rocky Mountains, of the occurrence of two species of marine mollusks and living crabs belonging to marine forms, and tiny air-breathing mollusks peculiar to the Gulf coast and West Indies, point as distinctly to the past connection of that region with the ocean as the records of marine life left in the rocks. And more than this, the survival of these few forms gives us a conception of the thousands of animals which have succumbed to the changed conditions. Connected with the evidences of recent elevation of this region are the discoveries of Marsh in finding that, when the gill-bearing salamander *Siredon* is brought down from the colder waters of the Rocky Mountains to the warmer waters below, a complete change takes place in a loss of the gills and the conversion of the animal into the air-breathing genus *Amblystoma*.

This exhibits on a wider scale the experiments often performed in keeping tadpoles in the dark and cold, and indefinitely retarding their development, thus forcing them, as it were, to retain their earlier condition. Among the many millions of individuals of Amblystoma, some must have presented the anomaly of a premature development of their ovaries before the larval stage had passed away (similar cases being observed among insects), and thus it has been possible for them to perpetuate their kind in this stage. The Axolotl, having the longest persisted in this mode of growth, has become, as it were, almost fixed in these retrograde characters, only a

few examples being known in which the creatures have lost their gills and assumed the mature characters of Amblystoma, but with Siredon a change takes place with a proper change of surroundings.

To American students we are indebted for most valuable contributions regarding the effect of cave influences on animals living within their boundaries. Looking at the cave fauna with its peculiar assemblage of animals, it would seem that here, at least, the question as to the effects of certain external influences, or the absence of others in modifying structure, might be found.

Many years ago the editors of *Silliman's Journal* addressed a letter to Prof. Agassiz respecting the blind fishes of the Mammoth Cave, and asked his opinion as to whether their peculiar structure was due to their cave life, or whether they had been specially created. Agassiz's [1] reply is consistent with his belief. He says, "If physical circumstances ever modified organized beings, it should be easily ascertained here." He then expresses his conviction that "they were created under the circumstances in which they now live, within the limits over which they range, and with the structural peculiarities which characterize them at the present day," adding frankly, however, that these opinions are mere inferences.

With the contributions on cave insects by the eminent zoölogist Schiödte, and our own naturalists as well, we have now overwhelming proof that the blind fishes and numerous other cave animals are marked with peculiarities impressed upon them by the unusual environments to which they have been subjected.

In a work on the animals of the Mammoth Cave, by Dr. A. S. Packard and Prof. Putnam, the first-named writer quotes the results of Schiödte, wherein he shows the existence of twilight animals in which but slight modification occurs, while in darker places the changes become more profound.

Dr. Packard [2] sums up the results of his work as follows: "We then see that these cave animals are modified in various ways, some being blind, others very hairy, others with long appendages; all are not modified in the same way in homologous organs, another argument in proof of their descent from ancestors whose habits varied as their out-of-door allies do at present."

Prof. E. D. Cope,[3] in an article on the fauna of Wyandotte Cave, in commenting on the loss of eyes in cave animals from absence of light, and consequent disuse, says that, to prove it, "we need only to establish two or three propositions: 1. That there are eyed genera corresponding closely in other general characters with the blind ones. 2. The condition of the visual organs is in some cave type variable. 3. If the abortion of the visual organs can be shown to take place coincidently with general growth to maturity, an important

[1] *American Journal of Science*, second series, vol. xi., p. 128.

[2] "Life in the Mammoth Cave," p. 27. [3] *American Naturalist*, vol. vi., p. 415.

point is gained in explanation of the *modus operandi* of the process." He then proceeds to point out a number of related genera in which the external ones present eyes, while the cave forms are blind. As to variability, he cites the blind siluroid fish from Conestoga, Pennsylvania, showing that, while all of several specimens were blind, the degree of atrophy was marked not only in different fishes, but even on different sides of the same fish. In some the corium was perforate, in others it was imperforate. In some the ball of the eye was oval, in others collapsed.

We have in the meagre fauna of the caves convincing proof of the gradual undoing of parts—so to speak—on the withdrawal of influences favorable to them; even so exquisite a structure as the eye as a result of selection almost inconceivable, yet not only becoming rudimentary, but almost disappearing, by the withdrawal of those influences which were in part conducive to its building up. So distinct are these undoing stages that, were we sure of the stable variability of all of them, we could with certainty indicate the relative age of each cave inhabitant.

Prof. Alpheus Hyatt and Prof. E. D. Cope almost simultaneously established a number of propositions relating to certain large groups of animals which had never been recognized before. The theory of acceleration and retardation in which certain groups acquire rapidly new characters, while corresponding groups acquire the same characters more slowly, forms a portion of the theory of these naturalists. Prof. Hyatt has shown among Ammonites a parallel between the life-stages of the individual and similar stages in the group based upon an examination of suites of specimens as studied by him in Europe and America. It is utterly impossible to do the slightest justice to the thoroughly original views of these gentlemen without the aid of explanatory diagrams. While reluctantly abandoning the attempt, I must at the same time express the regret that neither of these investigators has seen fit to present to the public an illustrated and simple outline of the main features of their theories and the facts: Prof. Cope basing in part his propositions on groups of animals, many of which comprise fossil forms brought to light in the West, of which but few restorations have yet been made; and Prof. Hyatt basing his work on fossil Ammonites from the Jurassic and adjacent beds of Europe, of which but one complete collection is to be found in this country.

Surely, with this unfamiliar material, an excuse may be offered in not attempting a popular presentation of propositions and laws, some doctrinal and others theoretical, which must yet be looked upon as profound and permanent additions to the philosophy of evolution. A reference may be made to Prof. Cope's essays, entitled "Origin of Genera," "On the Method of Creation of Organic Types," "Consciousness in Evolution," "On the Theory of Evolution," and numer-

ous other memoirs from which may be gathered the author's views on the subject. The essays of Prof. Hyatt, "On the Parallelism between the Different Stages of Life in the Individual and those in the Entire Group of the Molluscan Order Tetrabranchiata," "Reversions among Ammonites," "Evolution of the Arietidæ," "Genetic Relations of the Angulatidæ," "Abstract of a Memoir on the Biological Relations of the Jurassic Ammonites," are altogether too technical to condense into an address of this nature. It need hardly be mentioned that in these memoirs invaluable contributions are made to the doctrines of natural selection. And now we come to the most difficult part of our work: to compass within the limits of a few pages the magnificent discoveries of Leidy, Marsh, and Cope, in the rich fossiliferous beds of the West. The wonders are so unique and varied; they have been poured upon us with such prodigality of material and illustration, that one is baffled in an attempt to compass their characters, or to picture them as realities. When Darwin offered the imperfection of the geological record as possibly accounting for the absence of intermediate forms which might have existed, he was at once met by a series of protests so strenuous, and at the same time so specious, that they had their full weight in staying the force of that prophetic chapter. Darwin, in this chapter, distinctly stated that not only were there forms which had never yet been seen, owing to the imperfection of the geological record, but that time might possibly bring them to light, and, when discovered, we should have revealed to us intermediate characters which would connect widely-separated groups as they are recognized to-day.

Behold the prophet! Animals have been discovered, not only showing the characters of two widely-separated groups, but in some cases of three groups as they now appear. How distinct the hoofed quadrupeds, the carnivora, and the rodents, appear to-day! Yet here are discovered ancestors of these widely-separate groups, in which are contained in one individual the characters of all three! Of the ungulates with the perissodactyle foot, there have been discovered a large number of tapiroid forms allied to Paleotherium; others which, like Anchitherium, wonderfully fill the gap between the horse and forms lower down; a large suite of rhinocerotic creatures of strange character and enormous size; a great number of species of three-toed horse, some no larger than foxes, and with these a perplexing maze of deer, antelopes, sheep, camels, hippopotami, and pig-like animals, ruminant-like beasts, some of them not larger than an ordinary squirrel: a curious group, comprising a large number of species with characters intermediate between the pigs and ruminants. Prof. Flower, the great English osteologist, confesses that these forms completely break down the line of demarkation between them, and adds that "a gradual modification can be traced in the characters of the animals of this group, corresponding with their chronological

position, from the earlier more generalized to the latest comparatively specialized forms, thus affording one of the most complete pieces of evidence that are known in favor of a progressive alteration of form, not only of specific, but even of generic importance through advancing ages." The probable home of the Camelidæ has been revealed in the discovery of llama-like creatures, gigantic mammals, in some cases exceeding the elephant in size, but with a diversity of characters hitherto unseen either in recent or fossil forms, combining as they did the characters of perissodactyle and proboscidian.

A numberless variety of Carnivora, many of them embracing the most generalized groups, have been brought to light, such as creatures between the wolf and the opossum, generalized dogs, and sabre-toothed cats.

A great many species belonging to the Rodentia, Insectivora, and Chiroptera, have been identified; still more wonderful is a group of creatures so unlike any beast heretofore known that Prof. Marsh has made a new order to include them under the name of *Tillodontia*. They combine the characters of several distinct groups, namely, the carnivores, ungulates, and rodents, and some of them in size equaling the tapir. Of great interest also is the discovery of fifteen new genera, belonging to low forms of primates. All of these creatures, embracing hundreds of species, are generalized in a high degree. New orders have been erected to embrace some of them. One has only to understand the specialization of modern animals to appreciate the generalized character of these early forms.

Prof. Marsh has shown that all the ungulates in the Eocene and Miocene had upper and lower incisors; and, again, that all the Eocene and Miocene mammals, including the Carnivora, had two of the wrist-bones, the scaphoid and lunar, as distinct bones.

The class of birds so long represented as a closed type can no longer occupy that isolated position. The proper interpretation of archæopteryx has, in the discoveries of Marsh, new interest. He has discovered a number of species of birds, for which a new sub-class is made. This sub-class will embrace two sub-orders, one in which the creatures had teeth contained in grooves in the jaws; the other had true teeth in the sockets. The first were swimming-birds of gigantic size, with rudimentary wings; the second embraced small birds, with powerful wings and bi-concave vertebræ.

Prof. Cope has also brought to light a remarkable gigantic bird from the Eocene of New Mexico; its size indicates a species with feet twice as large as those of the ostrich. He shows it to be distinct from any of the genera of *Struthionidæ* or *Dionornithidæ*. Besides all these wonders, a host of new forms of reptiles and fishes have been discovered by these indefatigable explorers—huge pterosauria discovered by Marsh with a spread of wing of twenty-four feet; and of more special interest is the fact that no trace of teeth can be found in the jaws.

It is impossible for me to more than allude to these remarkable additions to our knowledge of these early forms, and until they have all been figured with natural outlines, and perplexing questions as to priority in discovery rectified, it will be difficult in some cases to accredit individual work. But in the light of these profound revelations, how blind seem the attempts to establish a classification on the forms heretofore familiar to us, and to rear these into circumscribed groups between which it was asserted no forms of intermediate kinds were to be expected! With the twenty-five or thirty species of fossil horses at our command, some with four toes, others with three, in various stages of reduction, it is interesting to bring back to mind the earnest Geoffroy St.-Hilaire painfully endeavoring to trace the genealogy of the horse, with a few widely-separated forms of extinct mammals as his only guide in the work.

The special investigations of Marsh and Leidy reveal an almost unbroken line from our present horse with its simple toe, and two rudimentary metatarsals in the shape of the splint-bones, to a creature in which metatarsals support rudimentary toes, and still other forms in which these rudimentary toes are working-toes, and below that again another form in which a fourth toe is seen as a rudiment, till forms are reached in which all the toes rest on the ground. It is still more striking to study attentively those earlier generalized horses with four toes, and follow the successive reduction in the number of toes as the later formations are reached, till in the latest deposits and at present we have the modern specialized horse with but a single toe, the lost toes represented by two slender bones hidden beneath the flesh. And now comes crowning proof that our modern horse has been derived from some three-toed progenitor, for in certain instances horses have come into existence with splint-bones developed into sturdy bones sustaining at the extremities phalangeal bones, and outside accessory hoofs! Such freaks of Nature demand an explanation. They receive a rational one through the theories of Darwin. Without the law of reversion, we are left in blind bewilderment.

While all these facts in overwhelming array testify to the extreme mutability of forms, induced oftentimes by apparently the most trivial of causes, and set at rest the question as to the fixedness of species, they show at the same time the richness of that store from which by natural selection forms may be selected.

Realizing the uniformity of Nature's laws, the human mind bravely asks, "Do these wonderful interpretations throw any light upon the origin of man?"

Rigidly adhering to the inductive method, science is prepared to show that man did not appear suddenly and free from those animal proclivities and passions which make him a sinful creature, but that he has risen from a lowly origin, and his passions and desires, but feebly repressed, may be as surely traced to ancestral traits, as the

aberrant muscles in his structure may be recognized in some degraded progenitor. And in proof of this there is established a series of facts of precisely the same nature as is seen in those discoveries which link the horse in an almost unbroken line to earlier and more generalized animals.

It is instructive to read the discussions in relation to man's position in Nature as represented by Agassiz, Morton, and others.

The position that these eminent men were justified in taking shocked the Church, and received from her the same vigorous denunciations that Darwin was forced to bear at a later day.

The systematist, in formulating the separate species and genera of the apes and monkeys, was early led to see that man also in various parts of the world presented differences quite as striking, and if it were assumed, as indeed it was, that the peculiarities among men were only varietal, then it could be claimed with equal emphasis that the differences among apes were only varietal. Agassiz, in his keen grasp of things, readily saw this, and, since the races of men revealed differences just as specific in their characters as the animals immediately below them, he was forced to admit the plurality of origin of the human race. He says:

"Unless we recognize the differences among men, and we recognize the identity of these differences with the differences which exist among animals, we are not true to our subject, and, whatever be the origin of these differences, they are of some account; and if it ever is proved that all men have a common origin, then it will be at the same time proved that all monkeys have a common origin, and it will by the same evidence be proved that man and monkeys cannot have a different origin."

He confesses that he "saw the time coming when the position of the origin of man would be mixed up with the question of the origin of animals, and a community of origin might be affirmed for them all." With these convictions it is not surprising that he should have been led to express the opinions regarding the diversity of the human race that we find recorded.

Agassiz, in the meetings of the American Academy, repeatedly and in various ways illustrated the diversity of the human race. In one place he alludes to the difficulty in defining the species of man, and says the same difficulties occur in defining the species of anthropoid apes. We quote from the records:

"The languages of different races of men were neither more different nor more similar than the sounds characteristic of animals of the same genus; and their analogy can no more be fully accounted for on any hypothesis of transmission or tradition than in the case of birds of the same genus uttering similar notes in Europe and America."—("Proceedings of the American Academy," vol. iii., p. 6.)

Again, in a later volume, he expresses a general disbelief in the supposed derivation of later languages from earlier ones. He re-

garded each language and each race as substantially primordial, and ascribed their resemblances to a similarity in the mental organization of the races.

This extract illustrates the extremity to which one is logically driven if he accepts the hypothesis of special creation, and these words are quoted, not with the belief that at the present time they would have been uttered, but as illustrating the necessary admissions with the theory of plurality of origin. In precisely the same manner that Whitney, Müller, and other eminent philologists, have shown the outgrowth of present existing languages from primitive forms of language, so science is prepared to show the outgrowth of present men from primitive forms of animals. Agassiz was bitterly assailed by the Church for the bold attitude he assumed regarding the plurality of origin of the human race, though now that science will show that after all man has originated from a common centre, it seems no better satisfied. The facts bearing on man's lowly origin have been fully contributed by American students, and, as all intelligent men understand the bearing of these facts on the question, it is only necessary to allude to them here. If man has really been derived from an ancestor in common with the ape, we must expect to show—1. That in his earlier stages he recalls certain persistent characters in the apes; 2. That the more ancient man will reveal more ape-like features than the present existing man; and, 3. That certain characteristics pertaining to early men still persist in the inferior races of men.

Prof. Wyman[1] points out certain resemblances between the limbs of the human embryo and the permanent condition of the limbs of lower animals. In some human embryos about an inch in length he found that the great-toe was shorter than the others, and, instead of being parallel to them, projected at an angle from the side of the foot, thus corresponding with the permanent condition of this part in the Quadrumana.

In some observations made on the skeleton of a Hottentot, Prof. Wyman[2] calls attention to the complete ossification of the nasal bones, no trace of a suture remaining. This was more noticeable as the individual was young, and the other bones were immature, and had an interest "in connection with the fact that the nasal bones are coössified at an early period in the monkeys and before the completion of the first dentition in gorillas and chimpanzees." Careful measurements of the pelvis also revealed quadrumanous features, though "the resemblance is trifling in comparison with the differences."

In a study of the crania, Wyman[3] found differences in the relative position of the *foramen magnum*. In the North American Indian this opening was farther back than in the negro, while some crania from Kauai presented this opening still farther back than in the

[1] "Proceedings of the Boston Society of Natural History," vol. x., p. 185.

[2] Ibid., vol. ix., p. 352.

[3] Ibid., vol. xi., p. 447.

Indian; and more than half the lot from Kauai had the peculiarity in the nostrils first pointed out in the negro by Dr. John Neil, of Philadelphia, namely, the deficiency of the sharp ridge which forms the lower border of the opening. In its place is a rounded border, or an inclined plane.

This feature occurs very frequently in different races, but more rarely in Europeans. It is, however, never absent in the apes. Prof. Wyman, in studying the characters of certain ancient crania from a burial-place near Shell Mound, Florida, observed the *foramen magnum* quite far back, and remarks on the massive character of the bones composing the skull, the parietal being nearly twice the thickness of ordinary parietals, while the general roughness of the surfaces for muscular attachments on the hinder part of the head is very striking.[1]

In certain measurements of synostotic crania, Prof. Wyman found that the length of the parietals was twenty-four millimetres above the average, the parietals being lengthened from before backward, the frontal and occipital being but slightly augmented. Now, in the much-discussed Neanderthal skull, wherein it is urged by Dr. Davis that it is a synostotic skull, though denied by Huxley, Wyman shows that the parietals measure nine millimetres *below* the average, which is certainly against the view that the Neanderthal skull is synostotic.[2]

In an essay entitled "Observations on Crania and Other Parts of the Skeleton," Prof. Wyman shows that the relative capacity of the skull "is to be considered merely as an anatomical and not as a physiological characteristic,"[3] a most important distinction certainly in considering the large capacity of certain ancient skulls, since we must know the quality as well as the quantity in order to assume the intellectual position of the races. In this essay are also quoted the results of a large series of measurements made by Dr. B. A. Gould, in which it is shown that the arms of the blacks are relatively longer as compared with the whites, in this respect approaching the higher animals, a confirmation of the observations made by Broca, Pruner Bey, Lawrence, and others.

The perforation of the humerus, which occurs in the apes quite generally, was found to occur rarely in the white race. Of fifty humeri, Wyman found but two perforated, while of Indian humeri he found thirty-one per cent. perforated. In some of the remains of ancient men there has been found a remarkable lateral flattening of the tibia, unlike anything found at present, but always characteristic of the earliest races. These tibiæ have received the name of platycnemic tibiæ.

[1] "Fourth Annual Report of the Peabody Archæological Museum. Cambridge."

[2] "Proceedings of the Boston Society of Natural History," vol. xi., p. 455.

[3] "Fourth Annual Report of the Peabody Archæological Museum."

Wyman[1] quotes Broca as saying that the measurements of these tibiæ resemble the ape, and, what is more striking, in a small number of instances "the bone is bent and is strongly convex forward, and its angles so rounded as to present the nearly oval section seen in the apes." The occurrence of these platycnemic tibiæ has been noticed by several investigators. They have been obtained from the mounds of Kentucky by Mr. Carr, Mr. Lyon, and Prof. Putnam. Prof. Wyman found them in Florida mounds. To Mr. Henry Gillman, of Detroit, science is indebted for the discovery of the flattest tibiæ ever recorded, exceeding even those discovered in Europe. Mr. Gillman has opened a number of mounds along the Detroit and Rouge Rivers in Michigan, and assiduously studied the characters of these remains, which indicate a very ancient race of men. Many of these tibiæ he has sent to the Peabody Archæological Museum at Cambridge. Associated with these remarkable tibiæ he found large numbers of perforated humeri.

At the Detroit meeting of the Association, Prof. W. S. Barnard showed that the muscles which move the fingers and toes have been developed from one common muscle, and, in studying the various degrees of specialization of the muscles which move the hand and foot in the gorilla and lower apes, he finds that in the foot "man remains a creature of the past not modified by that which makes him a man, the brain. The hand has been modified and perfected by its services to the brain." Prof. Barnard also contributed another essay, entitled "Comparative Myology of Man and the Apes." From very careful studies he is led to believe that the relative position of the origin of the muscles is more constant than that of their insertions. In this examination he brings to light a muscle which Traill dissected in the higher apes, and which he called the *scansorius*, and this was supposed to have no representative in man.

Traill was followed by Wyman, Owen, Wilder, and Bischoff, who, in a controversy with Huxley, argued from this muscle against the simian origin of man. Mr. Barnard now shows that Traill was mistaken, and that other naturalists were misled by the weight of his authority. What Traill interpreted as the *gluteus minimus* is the *pyriformis*, and what he figured as a new muscle separating the apes from man, the *scansorius*, is the *homologue* of our *gluteus minimus.*

From gradually accumulating data, in regard to microcephalic skulls, it would seem as if Carl Vogt were right in judging them to be cases of reversion. Prof. Wyman says, in regard to a microcephalic skull from Mauritius, that, "taking together the high temporal ridges, the union of the temporals with the frontals, the projection of the jaws, the narrow and retreating forehead, the small capacity, and the form and proportions of the nasal openings, the general resemblance to that of an ape is most striking, and seems to justify Vogt's expres-

[1] "Fourth Annual Report of the Peabody Archæological Museum."

sion of a man-ape, it being understood that the skull we are describing is not a natural, but an anomalous formation."[1]

It would be difficult to imagine, indeed, that mere reduction in the size of the brain, through arrest of development, should produce a series of characters so closely resembling the apes as is found to be the case in so many widely-separated examples. Thus, in the Mauritius microcephalic skull the capacity is only twenty-five cubic inches. The jaws are extremely prognathous, the zygomatic arches stand out wide and free, and the temporal ridges approach within one and a quarter inch. If such examples should prove to be veritable cases of reversion, then we have a parallel in the startling appearance of the long-lost rudimentary toes of the horse, traces of which are only seen in the hidden splint-bones. In the "Seventh Annual Report of the Archæological Museum," Prof. Wyman describes a microcephalic skull from the ancient *huacals* of Peru. Its capacity is only thirty-three cubic inches; "the frontal bone is much slanted backward, has a decided ridge corresponding to the frontal suture, and is slightly concave on each side of it."

Wyman states that the bones of the head are well formed, though, from the diminutive size of the brain, idiocy must have existed.

Associated with the remarkable collection of platycnemic tibiæ and perforated humeri discovered by Mr. Henry Gillman, we should have expected some anomalous forms of crania, and in this expectation we are not disappointed.

In company with two skulls which appear to be normal, Mr. Gillman discovered one of most remarkable proportions. Wyman considers it a case of extreme individual variation, and not the result of artificial deformity. The skull in question has only a capacity of fifty-six cubic inches. The average capacity of Indian crania, according to Morton's measurements, being eighty-four cubic inches, and the minimum capacity being sixty-nine cubic inches, the skull of Gillman is therefore thirteen cubic inches less than the smallest Indian skull heretofore described. But more extraordinary still is the approximation of the temporal ridges. While in ordinary crania the separation of these ridges is usually from three to four inches, and never less than two inches, in this unique skull from the Detroit River mound the ridges in question approach within three-quarters of an inch, in this respect, as Wyman says, presenting the same condition as that of the chimpanzee. A rounded median crest can be distinctly seen and felt between these ridges, and the skull is markedly depressed on each side for the passage of the powerful mastoid muscles.

Is this, too, a case of partial reversion? Such extraordinary forms as the Neanderthal and Engis skulls, and the one above cited, with the La Naulette and other lower jaws, could not have been uncommon in those early days, since the chances against finding them

[1] "Seventh Annual Report of the Peabody Archæological Museum."

would be simply enormous, unless, indeed, they were of common occurrence. Looking at these remains as at the remains of other mammals, we must admit either that these low characters represent retention of ancestral peculiarities, or that they are cases of reversion. In considering the Neanderthal skull, with its retreating frontal, its enormous frontal crest, and other anthropoid characters, Huxley is led to say that at most there is "demonstrated the existence of a man whose skull may be said to revert somewhat toward the pithecoid type."

To a mind unbiased by preconceived opinions, and frankly willing to interpret the facts as they stand revealed by the study of these ancient remains the world over, the evidence of man's lowly origin seems, indeed, overwhelming.

Looking at the whole question impartially, we find that among recent men there are high types as well as low types, with a variation so great as to have induced Agassiz, Morton, and others, to consider them specific. And while, as Wyman asserts, no one race possesses all the low characters, yet with the relatively long arms, the tendency of the pelvis to depart from the normal proportion, and numerous other facts of like significance, there are yet retained among some of them more resemblances to the higher apes than can be found among others.

Prof. Cope, not content with tracing man back to some ape-like progenitor, has, in a suggestive way, considered man's relations to the Tertiary mammalia. In a communication to the Association at Detroit, on this subject, he prefaced his paper by saying that in the doctrine of evolution two propositions must be established: 1. That a relation of orderly succession of structure exists, which corresponds with a succession in time; 2. That the terms (species, genera, etc.) of this succession actually display transitions or connections by intermediate forms, whether observed to arise in descent, or to be of such varietal character as to admit of no other explanation of their origin." He shows that the primary forms of mammalia are strongly indicated in the structure of the feet, and also in the character of the teeth. In recent land-mammals there are several types of foot to be recognized, the many-toed plantigrade, the carnivorous, the ox, and the horse types. Among the earlier types of the Eocene, he finds the most generalized type in the Coryphodon of Owen (Bathmodon of Cope). This creature was plantigrade, with a short calcaneum, and an imperfect hinge for the foot. From this generalized form he traces a line of succession of intermediate forms to the horse on the one hand, and the ox on the other.

The Coryphodon was one of the earliest known mammals, while the horse and the ox preceded man by a single geological period. Without entering into a technical description of the successive forms presented by Prof. Cope, we may quote his words wherein he shows

that "the mammals of the Lower Eocene exhibit a greater percentage of types that walk on the soles of their feet, while the successive periods exhibit an increasing number of those that walk on the toes; while the hoofed animals and Carnivora of recent times nearly all have the heel high in the air, the principal exceptions being the elephant and bear families." After presenting the gradual osteological changes of the foot, from the earlier types to the later ones, through several lines of descent, considering also the teeth as well, he says: "The relation of man to this history is highly interesting. Thus, in all generalized points, his limbs are those of the primitive type, so common in the Eocene. He is plantigrade, has five toes, separated tarsals and carpals, short heel, rather flat astragalus, and neither hoofs nor claws, but something between the two; the bones of the forearm and leg are not so unequal as in the higher types, and remain entirely distinct from each other, and the ankle-joint is not so perfect as in many of them. In his teeth his character is thoroughly primitive. . . .

"His structural superiority consists solely in the complexity and size of his brain. A very important lesson is derived from these and kindred facts. The monkeys were anticipated in the greater fields of the world's activity by more powerful rivals. The ancestors of the ungulates held the fields and the swamps, and the Carnivora, driven by hunger, learned the arts and cruelties of the chase. The weaker ancestors of the Quadrumana possessed neither speed nor weapons of offense and defense, and nothing but an arboreal life was left them, where they developed the prehensile powers of the feet. Their digestive system unspecialized, their food various, their life the price of ceaseless vigilance, no wonder that their inquisitiveness and wakefulness were stimulated and developed, which is the condition of progressive intelligence"—adding that "the race has not been to the swift, nor the battle to the strong." Prof. Cope shows in this case that "the survival of the fittest has been the survival of the most intelligent, and natural selection proves to be, in its highest animal phase, intelligent selection."

Prof. Fiske has in a clearer way shown that when variations in intelligence became more important than variations in physical structure, then they were seized upon, to the relative exclusion of the latter.

It is intelligent strength, other things being equal, that conquers the savage, and the gradual selection of the best and biggest brains is not seen alone in man.

In one of the most significant discoveries of Prof. Marsh, the mammalia are found to show an increase in the size of the brain coincident with their succession in the rocks.

One of the most extraordinary mammals from the Tertiary beds of the West is the Dinoceras, with its rhinoceros and elephant characters, its skull ornamented with prominent tubercles, its unique den-

tition, embracing large cutting tusks, and altogether forming a beast like the fabled monsters of old.

A study of its cranial cavity, made by Prof. Marsh, shows that its brain was proportionally smaller than that of any known mammal. Indeed, it was almost reptilian, and of such diminutive size that it could have been drawn through the neural canal of all the presacral vertebræ. Prof. Marsh has followed up this discovery with the most important results, and is now prepared to state the following conclusions:

1. That all the Tertiary mammals had small brains.
2. There is an increase in the size of the brain during this period.
3. This increase was mainly confined to the cerebral hemispheres or higher portion of the brain.
4. In some groups the convolutions of the brain have gradually become more complicated.
5. In some the cerebellum and olfactory lobes have even diminished in size.

He also finds some evidence that the same general law holds good for birds and reptiles from the Cretaceous to the present time.[1]

Thus we have in other groups as well as man convincing proof that, with successive survival of forms, there is a corresponding survival of larger brains.

Prof. Shaler[2] has offered some suggestive thoughts in showing the intense selective action which must have taken place in the shape and character of the pelvis in man, on his assumption of the erect position—the caudal vertebræ turning inward; the lower portion of the pelvis drawing together to hold the viscera, which had before rested on the elastic abdominal walls; the attending difficulties of parturition, and other troubles in those parts—all pointing to the change which has taken place.

In this connection Prof. Shaler remarks that the question of labor in woman must not be overlooked from this standpoint.

In a memoir on the shell-heaps of Florida, by Prof. Wyman, wherein he describes a number of low characters in man already alluded to, he gives the following conclusions: "The steady progress of discovery justifies the inference that man in the earlier periods of his existence, of which we have any knowledge, was at most a savage, enjoying the advantage of a few rude inventions. According to the theory of evolution, which has the merit of being based upon, and not inconsistent with, the observed analogies and processes of Nature, he must have gone through a period, when he was passing out of the animal into the human state, when he was not yet provided with tools of any sort, and when he lived the life of a brute."[3]

[1] *American Journal of Science*, vol. xii., July, 1876.

[2] "Proceedings of the Boston Society of Natural History," vol. xv., p. 188.

[3] "Memoirs of the Peabody Academy of Sciences," vol. i., part iv.

These words have no obscure significance, and when we regard the character of the one who wrote them, his cautious methods of research, and the long deliberation he was wont to give to all such questions, then they become doubly important.

Recognizing clearly the existence of these lower and earlier stages in man, it has been one of the most difficult problems to solve the first steps toward his society and family relations. Prof. John Fiske, in his "Outlines of Cosmic Philosophy," has given for the first time a rational explanation of the origin and persistence of family relations, and thence communal relations, and, finally, society.

Never before has there been presented so clear an idea of man's physical changes, and the effects of natural selection in seizing upon attendant or correlated nervous changes, as in the work of this author.

Prof. Fiske says: "Civilization originated when in the highest mammals variations in intelligence became so much more important than variations in physical structure that they began to be seized upon by natural selection, to the relative exclusion of the latter." [1]

Starting from the researches of Sir Henry Maine, Lubbock, and others, he finds social evolution must have originated after families temporarily organized among the higher mammals had become permanently organized. But how this step was effected has been an insoluble problem. Bagehot, in his remarkable work on "Physics and Politics," says: "It is almost beyond imagination how man, as we know man, could by any sort of process have gained this step in civilization." Darwin supposes that men were originally weak and inoffensive creatures, like the chimpanzee, and were compelled to band together to make up in combined strength what they lacked as individuals.

That man, for his age, is a weak animal physically, there can be no doubt. Fiske shows that "increase of intelligence in complexity and specialty involves a lengthening of the period during which the nervous connections involved in ordinary adjustments are becoming organized." From these conditions arose the phenomena of infancy, and he shows that with increase of intelligence infancy becomes longer. In the human race it is longer than in any other mammal, and much longer in civilized man than in the savage.

In the orang-outang the infant does not begin to walk till it is a month old, and in performing this act it holds to various objects for support, as in the human infant. Previous to that time it reposes on its back, and becomes absorbed in gazing at its hands and feet. Now, still lower down among the monkeys, at the age of one month the young are fully matured so far as walking and prehension are concerned. It is shown, furthermore, that where infancy is very short, parental feeling may be intense for a while, but soon dies out,

[1] "Cosmic Philosophy," vol. ii., p. 340.

and the offspring of one becomes of no greater interest than those of a stranger, "and in general the duration of the feelings which insure the protection of the offspring is determined by the duration of the infancy. . . .

"Hence if long infancies could have suddenly come into existence among a primitive race of ape-like men, the race would have quickly perished from inadequate persistence of parental affection." Prof. Fiske, in a most reasonable way, shows that "the prolonged helplessness of the offspring must keep the parents together for longer and longer periods in successive epochs; and when at last the association is so long kept up that the older children are growing mature while the younger ones still need protection, the family relations begin to become permanent. The parents have lived so long in company that to seek new companionships involves some disturbance of ingrained habits, and meanwhile the older sons are more likely to continue their original association with each other than to establish associations with strangers, since they have common objects to achieve, and common enmities bequeathed, inherited or acquired with neighboring families."

In his chapter on the moral genesis of man Fiske maintains that "the prolongation of human infancy accompanying the development of intelligence, and the correlative extension of parental feeling, are facts established by observation wherever observation is possible; and to maintain that the correlation of these phenomena was kept up during an epoch which is hidden from observation, and can only be known by inference, is to make a genuine induction, involving no other assumption than that the operations of Nature are uniform. To him who is still capable of believing that the human race was created by miracle in a single day, with all its attributes, physical and psychical, compounded and proportioned, just as they now are, the present inquiry is of course devoid of significance. But for the evolutionist there would seem to be no alternative but to accept, when once propounded, the present series of inferences."

Recalling now the various evidences educed by Wyman, Giman, and others, regarding the anomalous characters of the remains of primitive man, it seems impossible that a mind unbiased by preconceived opinion should be able to resist the conviction as to man's lowly origin.

If we take into account the rapidly-accumulating data of European naturalists concerning primitive man, with the mass of evidence received in these notes, we find an array of facts which irresistibly point to a common origin with animals directly below us, and these evidences are found in the massive skulls with coarse ridges for muscular attachments, the rounding of the base of the nostrils, the early ossification of the nasal bones, the small cranial capacity in certain forms, the prominence of the frontal crest, the posterior position of

the *foramen magnum*, the approximation of the temporal ridges, the lateral flattening of the tibia, the perforation of the humerus, the tendency of the pelvis to depart from its usual proportions, and, associated with all these, a rudeness of culture and the evidence of the manifestation of the coarsest instincts. He must be blind indeed who cannot recognize the bearing of such grave and suggestive modifications. But what application are we to make of such revelations if we vividly receive them as such? We are no longer to rest with the blind fatalism of the Turks, or listless resignation of the masses, but are to make a living use of them. We are to trace evil and corrupt passions to their source. The dreadful outrages which shock us from time to time in the public prints are not instigated by an evil spirit, but are outbursts of the same savage nature which found more frequent expression years ago, and which are still present with the lower races of to-day. When the study of heredity reveals the fact that even the nature of vagabondage is perpetuated; when the surprising revelations of Margaret, mother of criminals, from whose loins nearly a thousand criminals have thus far been traced, are considered, common-sense will ultimately recognize that the imprisonment of a criminal for ten or twenty years is not simply to punish him or relieve the public of his lawless acts, but to restrain him from perpetuating his kind. No sudden revulsion of feelings and amended ways is to purify the criminal taint, but he is to be quarantined in just the same way that a case of the plague might be, that his kind may not increase. With these plain facts thoroughly understood, men high in authority must find some other excuse for the exercise of their pardoning power, and other reasons be given for allowing so large a proportion of criminals to go free. With the monstrous blot of Mormonism and free-love in our country, the statute-books are to be again revised from the standpoint of science, with its rigid moral and physical laws, and not from the basis of established usage or long-continued recognition.

THE LAWS OF HEALTH.

By THOMAS BOND, F. R. C. S.

On an average, one-half of the number of out-patients treated by a hospital-surgeon suffer from diseases due primarily to a want of knowledge of the laws of health and cleanliness. 1. The ignorance of hygienic laws, which affects so disastrously the health of the rich as well as the poor, exists chiefly in regard to dress, ablution, and ventilation. This statement may, at first, appear startling, but an enumeration of the diseases that can be constantly traced to the above causes will show upon how sound a basis the statement rests. The

following are examples: Varicose ulcers from dress; skin-diseases from want of cleanliness; chest-diseases and fevers from defective ventilation. The vast number of ulcerated legs treated in the outpatient department of hospitals, in workhouse infirmaries, and in private practice, arise from varicose veins. Now, a varicose ulcer is caused by a distended condition of the veins of the leg, which have to sustain the pressure of the blood caused by gravitation. In varicose veins, the valves which help to support the column of blood are to a great extent destroyed, through the veins having been distended by mechanical obstruction to the free return of the blood from the extremities, thereby distending the lower veins and separating the edges of the valves. Thus, the weight of an uninterrupted column has to be borne by the veins. This, of course, causes further distention, giving rise to congestion of the capillaries of the skin, and causing swelling, eczema, and ultimately ulceration. This is the varicose ulcer so common in the laboring-classes. It is always difficult to heal, and often impossible, except by prolonged rest in bed. Hence it is the dread of the surgeon, and the cause of misery to thousands. Varicose ulcers are seldom admitted into general hospitals, so that hundreds of poor families are driven to the workhouse, and such cases form a majority in the workhouse infirmary. The most frequent and flagrant cause of obstruction is the ordinary elastic garter. Children should never wear them at all, as the stockings can be perfectly well kept up by attachment of elastic straps to the waistband. If garters are worn, it is important to know how to apply them with the least risk of harm; at the bend of the knee the superficial veins of the leg unite, and go deeply into the under part of the thigh beneath the ham-string tendons. Thus a ligature below the knee obstructs all the superficial veins, but if the constriction is above, the ham-string tendons keep the pressure off the veins which return the blood from the legs; unfortunately, most people, in ignorance of the above facts, apply the garter below the knee. Again, in nine out of ten laboring-men, we find a piece of cord or a buckled strap tightly applied below the knee, for what reason I could never learn. Elastic bands are the most injurious. They follow the movements of the muscles, and never relax their pressure on the veins. Non-elastic bands during muscular exertion become considerably relaxed at intervals, and allow a freer circulation of the blood.

2. The habit of tight lacing again predisposes to varicose veins, in consequence of the abdominal viscera being pushed downward into the pelvis, causing undue pressure on the veins of the lower extremities when they enter the pelvis. Physicians also have reported numerous cases of heart and lung disease caused by this pernicious habit.

3. The use of dress is often misunderstood. Most persons evidently study and practise it with regard to appearance, or only to keep out wet and cold. The hygienic use of clothes, however, is not so much

to keep cold out as to keep heat in. The mistake is often made, of taking great care to put on extra wraps and coats when preparing for out-door exercise. This is not at all necessary in robust persons. Sufficient heat to prevent all risk of chill is generated in the body by exercise. The care should be taken to retain sufficient clothing after exercise, and when at rest, to prevent the heat passing out of the body. Indeed, persons very often catch chills from throwing off extra clothing after exercise, or from sitting about in garments, the material of which is not adapted to prevent the radiation of heat from the body. Linen and cotton under-clothing, when moistened by perspiration, parts with heat very rapidly, whereas flannel and silk, being non-conductors, prevent the rapid loss of heat.

4. The most recent offense against the laws of health is the habit of wearing false hair. The perspiration of the scalp is prevented, by the thick covering, from evaporating, thereby causing a sodden and weakened condition of the skin, which predisposes to baldness and other diseases of the scalp. Again, it produces headache and confusion of the intellectual faculties. We all know what a relief it is, during hard mental work, simply to raise one's hair by running the fingers through it. I should think literary ladies either do not wear false hair, or take it off when at work.

5. Ablution is another subject of paramount importance to health. Mr. Urquhart, the introducer of the Turkish bath into this country, is one of the benefactors of the age, and it is to be hoped some day there will be a bath in every town and village in England. Doctors are very much to be blamed for allowing themselves to be prejudiced against it. The usual opinion given by medical men to their patients is, that it is debilitating, and only to be borne by the robust. The reverse is really the case: it is stimulating and strengthening, it is a preventive as well as curative in disease. The effect of the Turkish bath on the skin is to cause an active condition of its functions of elimination, by removing the hardened epithelial scales, by removing the fat from the pores, and by causing the sweat-glands to maintain the activity of their functions, giving a general stimulus to the vital power of the skin. Again, it keeps the body in a state of perfect cleanliness, which is so essential to robust health; but these are not its only virtues—it promotes purity of mind and morals. The man who is accustomed to be physically clean shrinks instinctively from all contact with uncleanliness.

6. There are, however, certain precautions to be observed in the use of the baths. Persons who are apoplectic, or suffering from fatty degeneration of heart, should not venture to disturb the circulation by the excitement of baths. The first effect of Turkish baths is to stimulate the circulation, the second to cause active congestion of the skin, the third to produce profuse perspiration, the fourth to keep down the temperature of the body by rapid evaporation. On leaving the

Turkish bath the body should be douched with cold water; the capillaries are thus emptied of their blood by contraction, but immediately after the stimulation causes them to resume a state of activity, and produces vigorous circulation through the skin.

7. In taking a cold bath in the morning the same conditions should be present. The surface of the body should be warm and moist; therefore, the bath should be taken immediately on rising from the bed, and before the surface of the body has had time to cool or the capillaries to contract. The shock of the cold water should cause them suddenly to contract; then quick reaction will take place in the same way as after a Turkish bath. Unless this reaction occurs after the bath, there is great danger of getting a chill; at any rate, the full benefit of the bath is not obtained. Persons with weak circulation, who cannot take an ordinary morning bath, often derive great benefit from the Turkish bath. It opens the pores and improves the circulation of the skin, so that the shock of cold water can afterward be borne. The same persons can generally bear a cold bath if they get for a few minutes into a warm bath first, and then immediately plunge into cold water. By these means an active reaction is brought about. Warm baths should, in my opinion, never be taken on rising except under the above conditions, but warm baths at night are often desirable. They should be taken just before going to bed, when they have the effect of relaxing the muscular system and of promoting sleep by soothing the activity of the brain by the withdrawal of blood from it. I do not think warm baths at night are weakening, as the depression of vital energy which may occur is recovered during sleep. In river and sea bathing, persons should be careful not to remain in the water too long, nor should they exert themselves sufficiently to cause exhaustion, as the power of reaction is much impaired thereby; neither should persons get into cold water when cooling. The old-fashioned idea that persons should wait to cool before plunging into the water is a fallacy. There is no danger in plunging into the coldest water in a state of profuse perspiration, if the heart and arteries are in a healthy state. Of course, it would be unwise to do so immediately after a full meal, as the action of the heart might be impeded by the distended stomach.

8. Many persons complain of always getting up tired in the morning. This is very often due to defective ventilation of the bedroom, or from using an undue amount of bedclothes and bedding. Feather beds are too soft and yielding, and partially envelop the sleeper, thus producing profuse perspirations. The habit of lying too much under blankets is also very pernicious, by reason of the carbonic acid exhaled by the sleeper being respired. Again, it is a common error to suppose that, by simply opening a window a little at the top, a room can be ventilated. People forget that for proper ventilation there must be an inlet and outlet for the air. In bedrooms there is often

neither, and if there is a fireplace it is generally closed up. Again, it is a mistake to suppose that foul air goes to the top of a room. Certainly the heated air goes to the top, but the chief impurity, the carbonic acid, falls to the bottom. There is nothing so efficacious in removing the lower strata of air as the ordinary open fireplace, especially if there is a fire burning. The usual defect in ventilation is the want of a proper inlet for the air. If the window be open, the cold air, being heavier, pours down into the room, causing draughts; if the door be open or ajar, the same thing occurs. The perfection of ventilation may be obtained in any room with a fireplace by simply providing proper inlets for the air, and nothing answers so well for the purpose as the upright tubes invented by Mr. Tobin. By this means the heavier external atmosphere ascends vertically through the tubes like the jet of a fountain, displacing the warmer and lighter atmosphere of the room, which finds its exit up the chimney. The tubes should communicate with the outer air on a level with the floor, and should be carried vertically upward in the room for about four or five feet. A constant supply of fresh air is thus insured without the slightest liability to draught, as the current goes directly upward until it strikes the ceiling. It is then diffused downward, mixed with the heated air of the ceiling. The same principle can be carried out in any room with a sash-window, by cutting out two or three holes an inch wide and three inches long in the wood-work of the upper sash where it joins the lower one. The columns of air ascend directly upward, just inside the window, and mix with the heated air in the upper part of the room. If this system were universally carried out, we should hear less of rheumatism and chills caught by sitting in draughts.

9. Persons should cultivate the faculty of detecting sewer-gas in houses. Typhoid fever is often caused by the escape of this gas into the house through defect of the traps and drains. However bad the drains may be outside of the house, there is little to fear, provided the gas can escape externally. The following two very simple precautions would naturally diminish the cases of typhoid fever: First, every main drain should have a ventilating-pipe carried from it, directly outside of the house, to the top of the highest chimney; secondly, the soil-pipe inside the house should be carried up through the roof, and be open at the top.—*English Mechanic.*

CANINE SAGACITY.

A CORRESPONDENT hands us the following anecdotes illustrative of the remarkable reasoning powers of dogs:

The first case is one which occurred at a fashionable watering-place on the east coast of Ireland, some twenty years ago, and exhibits the remarkable sagacity displayed by a dog in carrying out the dictates

of the animal passion for revenge. The jetty which stretched along the small harbor was at that time used as a promenade by the *élite* among the sojourners on the coast, where, after the heat of the long summer days, they regaled themselves with the fresh evening breezes wafted in from the sea. Among the frequenters of this fashionable resort was a gentleman of some position, who was the owner of a fine Newfoundland dog, which inherited the time-honored possessions of that noble breed—very great power and facility in swimming; and, at the period of the evening when the jetty was most crowded with promenaders, his master delighted to put this animal through a series of aquatic performances for the entertainment of the assembled spectators. Amusement being at a premium on the coast, these nightly performances grew into something like an "institution," and the brave "Captain"—for such was his name—speedily became a universal favorite on the jetty. It happened, however, that among the new arrivals on the coast there came a certain major in her majesty's army, accompanied by two bull-dogs of unusual size and strength, and of great value; but, value in a bull-dog being inversely proportionate to its beauty, the appearance of the major and his dogs excited no very enthusiastic pleasure among the æsthetic strollers on the jetty. On the first night on which the major presented himself, nothing unusual occurred; and Captain dived and swam as before. But on the second evening the brave old favorite was walking quietly behind his master down the jetty, when, as they were passing by the major and his dogs, one of these ugly brutes flew at Captain, and caught him by the neck in such a way as to render his great size utterly useless for his defense. A violent struggle ensued, but the bull-dog came off the victor, for he stuck to his foe like a leech, and could only be forced to release his hold by the insertion of a bar of iron between his teeth. The indignation of the by-standers against the major was, of course, very great; and its fervor was not a little increased when they saw the poor Captain wending his way homeward, bleeding, and bearing all the marks of defeat. Some two or three evenings after this occurrence, when Captain again made his appearance on the jetty, he looked quite crestfallen, bore his tail between his legs, and stuck closely to the heels of his master. That evening passed away quietly, and the next, and the next, and so on for about a week—Captain still bearing the aspect of mourning. But one evening about eight or ten days after the above encounter, as the major was marching in his usual pompous manner along the jetty, accompanied by his dogs, something attracted his attention in the water, and, walking to the very edge of the jetty, he stood for a moment looking down into the sea. Scarcely had the two bull-dogs taken up their stand beside their master when Captain, seizing the opportunity for which he had so long looked, rushed at his former conqueror, and, catching him by the back of the neck, jumped off the jetty, with his foe in his mouth, down some twen-

ty feet or more into the sea. Once in the water, the power of his enemy was crippled, while Captain was altogether in his own element; and, easily overcoming all efforts at resistance, he succeeded in resolutely keeping the bull-dog's head under water. The excitement on the shore was, of course, intense. The major shouted, and called out: "My dog! my beautiful dog! Will no one save him?" But no one seemed at all inclined to interfere, or to risk his life for the ugly dog. At length the major called out: "I'll give fifty pounds to any one who will save my dog;" and soon afterward a boat which lay at some little distance pulled up to the rescue. Even then, however, it was only by striking Captain on the head with the oars that he could be forced to release his victim, which was taken into the boat quite senseless from exhaustion and suffocation, and was with difficulty brought to itself again. Captain, on the other hand, swam in triumph to the shore, amid the plaudits of the spectators, who shared, in sympathy at least, his well-earned honors of revenge.

More remarkable than the sagacity in carrying out the desire for revenge, displayed by the Newfoundland dog in the above case, is that which the following narrative illustrates: A gentleman of wealth and position in London had, some years ago, a country-house and farm about sixty miles from the metropolis. At this country residence he kept a number of dogs, and among them a very large mastiff and a Scotch terrier; and, at the close of one of his summer residences in the country, he resolved to bring this terrier with him to London for the winter season. There being no railway to that particular part of the country, the dog traveled with the servants in a post-carriage, and on his arrival at the town-house was brought out to the stable, where a large Newfoundland dog was kept as a watch-dog. This latter individual looked with anything but pleasure on the arrival of the little intruder from the country; and consequently the Scotch terrier had not been very long in his new home when this canine master of the stable attacked him, and, in the language of human beings, gave him a sound thrashing. The little animal could, of course, never hope by himself to chastise his host for this inhospitable welcome, but he determined that by some agency chastisement should come. Accordingly, he lay very quiet that night in a remote corner of the stable, but when morning had fully shone forth he was nowhere to be found. Search was made for him, as the phrase says, high and low, but without success; and the conclusion reluctantly arrived at was, that he had been stolen. On the third morning after his disappearance, however, he again showed himself in London, but this time not alone; for, to the amazement of every one, he entered the stable attended by the big mastiff from Kent. This great brute had no sooner arrived than he flew at the Newfoundland dog, who had so badly treated his little terrier friend, and a severe contest ensued, which the little terrier himself, seated at a short distance, viewed with the utmost dignity and

satisfaction. The result of the battle was, that the mastiff came off the conqueror, and gave his opponent a tremendous beating. When he had quite satisfied himself as to the result, this great avenger from Kent scarcely waited to receive the recognition of his master, who had been sent for immediately on the dog's arrival, but at once marched out of the stable, to the door of which the little terrier accompanied him, and was seen no more. Some few days afterward, however, the gentleman received a letter from his steward in the country, informing him of the sudden appearance of the terrier there, and his as sudden disappearance along with the large mastiff; and stating that the latter had remained away three or four days, during which they had searched in vain for him, but had just then returned home again. It then, of course, became quite clear that the little dog, finding himself unable to punish the town bully, had thought of his "big brother" in the country, had traveled over the sixty miles which separated them, in order to gain his assistance, and had recounted to him his grievance; it was plain also that the mastiff had consented to come and avenge his old friend, had traveled with him to London, and, having fulfilled his promise, had returned home, leaving the little fellow free from annoyance in the future.

The following well-known story is a strong example of the great intelligence which may be developed in a dog by careful training: A fashionably-dressed English gentleman was one day crossing one of the bridges over the Seine at Paris, when he felt something knock against his legs, and, looking down, he found that a small poodle-dog had rubbed against him, and covered his boots with mud. He was, of course, much annoyed, and execrated the little brute pretty freely; but when he got to the other side of the bridge, he had the boots cleaned at a stand for the purpose, and thought no more about the matter. Some days after this occurrence, however, he had occasion again to cross that bridge, and the same little incident occurred. Thinking this somewhat odd, he resolved to watch where the little dog went to; and, leaning against the side of the bridge, he followed with his eye the movements of his dirty little friend. He saw him rub against the feet of one gentleman after another, till he had exhausted all the mud off his once white skin, then rush off down the bank of the river, and there roll himself in the mud collected at the side. Having thus got a new supply of dirt, the little animal ran up to the bridge again, and proceeded to transfer it to the boots of the passers-by, as before. Having watched his movements for some time, the gentleman noticed that on one occasion, instead of running down to the river, he went off to the proprietor of the stand for cleaning boots, at the other end of the bridge, who received him very cordially. The truth then for the first time dawned on him, that the little animal belonged to the man who cleaned the boots, and was trained by him to perform these mischievous deeds, for the purpose of bringing in

custom. Being very fond of dogs, the Englishman resolved to purchase this clever little fellow, and bring him back to England with him. When, however, he went to the dog's master, that person at first denied any connection with him, and only admitted the ownership when he was perfectly satisfied that his interrogator had no connection with the police. For some time also he refused to part with the little poodle, saying that no money could pay him for the loss of his dog, who really made his living for him. Tempted, however, by a very high price, he at last consented to sell the dog; and the gentleman, a few days afterward, brought him over to England, traveling *via* Boulogne to Folkstone. His residence in England was some thirty or forty miles from Folkstone, and to this place he brought his little purchase. He had not been many days in his new home, however, when the little French poodle suddenly disappeared. Search was made for him everywhere, but to no effect. His new master offered a reward for him, but with the same result; and he had at last made up his mind that the little fellow had been either poisoned or stolen, when one morning, about six weeks after his mysterious disappearance, the gentleman received a letter from a friend in Paris telling him that his dog was back again there, and at his old trade of soiling boots in the interest of his former master. The little fellow, not liking the dullness of a country life, had resolved to return to his former home, and had made his way to Folkstone; there, as the gentleman afterward ascertained, he had got on board a steamer going to Boulogne, and from Boulogne had found his way back to Paris.

Of the foregoing three stories, the first two are probably even more remarkable than the last. The last (except as to the dog's finding its way back to Paris) illustrates only the possibility of developing in a dog, by the training of its natural intelligence, an almost human ingenuity. But it is by instilling into the dog the intelligence of a higher being that this skill is engendered. The spring of the intelligence is in the trainer, and it is to attain an object which the higher being, and not the lower, has in view. But in the first two cases the whole process is the dog's; the object to be secured, namely, revenge, is what the dog himself seeks, and the means by which that object is to be attained are devised and carried out by the instinct of the dog. That a dog should harbor revenge is, of course, not a very wonderful fact; but there is a calm reflection and a cool calculation displayed in the first two cases above given, which make them somewhat peculiar. If what we call instinct in these animals embraces powers so very like reason; if they are swayed by the same passions and affections which move us, and they are able to communicate to their fellows the feelings which stir them, and the external circumstances which bring those feelings into play, the border-line between man's mental territory and theirs becomes a little bit indefinite.—*Chambers's Journal.*

PROFESSOR HUXLEY'S LECTURES.[1]

II.

THE NEGATIVE AND FAVORABLE EVIDENCE.

In my lecture on Monday night I pointed out that there are three hypotheses which may be entertained, and which have been entertained, respecting the past history of life upon the globe. According to the first of these hypotheses, life, such as we now know it, has existed from all eternity upon this earth. We tested that hypothesis by the circumstantial evidence, as I called it, which is furnished by the fossil remains contained in the earth's crust, and we found that it was obviously untenable. I then proceeded to consider the second hypothesis, which I termed the Miltonic hypothesis, not because it is of any particular consequence to me whether John Milton seriously entertained it or not, but because it is stated in a clear and unmistakable manner in his great poem. I pointed out to you that the evidence at our command as completely and fully negatives that hypothesis as it did the preceding one. And I confess that I had too much respect for your intelligence to think it necessary to add that that negation was equally strong and equally valid whatever the source from which that hypothesis might be derived, or whatever the authority by which it might be supported.

I further stated that, according to the hypothesis of evolution, the existing state of things was the last term of a long series of antecedent states, which, when traced back, would be found to show no interruption and no breach of continuity. I propose in this and a following lecture to test this hypothesis rigorously by the evidence at command, and to inquire how far that evidence could be said to be indifferent to it, how far it could be said to be favorable to it, and, finally, how far it could be said to be demonstrative. From almost the origin of these discussions upon the existing condition—and the causes which have led to it—of the animal and vegetable worlds, an argument has been put forward as an objection to evolution, which we shall have to consider very seriously. I think that that argument was first clearly stated by Cuvier in his criticism of the doctrines propounded by his great contemporary, Lamarck. At that time the French expedition to Egypt had called the attention of learned men to the wonderful stores of antiquities in that country, and there had been brought back to France numerous mummified corpses of animals which the ancient Egyptians revered and preserved, the date of which, at a reasonable

[1] The second of three lectures on "The Direct Evidence of Evolution," delivered at Chickering Hall, New York, September 20th. From the report of the *New York Tribune*, carefully revised by Prof. Huxley.

computation, cannot be placed at less than 3,000 or 4,000 years before the time at which they were thus brought to light. Cuvier endeavored to ascertain, by a very just and proper method, what foundation there was for the belief in a gradual and progressive change of animals, by comparing the skeletons and all accessible parts of these animals, such as crocodiles, birds, dogs, cats, and the like, with those which are now found living in Egypt, and he came to the conclusion—a conclusion which has been verified by all subsequent research—that no appreciable change had taken place in the animals which inhabited Egypt. And he drew thence the conclusion, and a hasty one, that this fact was altogether opposed to the doctrine of evolution. The progress of research since Cuvier's time has furnished far stronger arguments than those which he drew from the mummified bodies of Egyptian animals. A remarkable case is to be found in your own country in the neighborhood of the magnificent falls of Niagara. In the immediate vicinity of the whirlpool, and again upon Goat Island, in the superficial deposits which cover the surface of the soil of the rock in those regions, there are found remains of animals in perfect preservation—shells belonging to exactly the same forms as at present inhabit the still waters of Lake Erie. It is evident from the formation of the country that these animal remains were deposited in the beds in which they occur, at the time at which the lake extended over the region in which they are found. This involves the necessity that they lived and died before the falls had cut their way back through the gorge of Niagara; and, indeed, it is possible to determine that at that time the falls of Niagara must have been at least six miles farther down the river than they are at present. Many computations have been made of the rate at which Niagara is thus cutting its way back. Those computations have varied greatly, but I believe I am speaking within the bounds of prudence if I assume that the falls of Niagara have not retreated at a greater pace than about a foot a year. Six miles, speaking roughly, are 30,000 feet; 30,000 feet, at a foot a year, are 30,000 years; and we are fairly justified in concluding that no less a period than this has passed since these shell-fish, whose remains are left in the beds to which we have referred, were deposited. But there is even still stronger evidence of the long duration of certain types than this. As we work our way through the great series of the Tertiary formations, we find species of animals identical with those which live at the present day, diminishing in numbers, it is true, but still existing in a certain number in the oldest of the Tertiary rocks. And not only so, but when we examine the rocks of the Cretaceous epoch itself, we find the remains of some animals which the closest scrutiny cannot show to be in any respect different from those which live at the present time. That is the case with one of the lamp-shells, a *Terebratula* which is found in the chalk, and which has continued as it was found, or with insignificant variation,

through to the present day. Such is the case with the *Globigerinæ*, the skeletons of which, aggregated together, form the great mass of our chalk in England. That *Globigerina* can be traced down to the *Globigerinæ* which live at the surface of our great oceans, and the remains of which, falling to the bottom of the sea, give rise to a chalky material. So that it must be admitted that certain species of creatures living at the present day show no sign of modification or transformation in the course of a lapse of time as great as that which carries us back to the period of chalk. There are groups of species so closely allied together that it needs the eye of a naturalist to distinguish them one from another. If we pay attention to these, we find that a vastly greater period must be allotted, in some cases, to these persistent forms. In the chalk itself, for example, there is the fish belonging to the highest and the most differentiated of osseous fishes, which go by the name of *Beryx.* That fish is one of the most beautiful of fossils found in our English chalk. It can be studied anatomically, so far as the hard parts are concerned, almost as well as if it were a recent fish. We find that that fish is represented at the present day by very closely-allied species which are living in the Pacific and Atlantic Oceans. But we may go still farther back, and we find, as I mentioned to you yesterday, that the Carboniferous formations in Europe and in America contain the remains of scorpions in an admirable state of preservation, and those scorpions are hardly distinguishable from such as now live. I do not mean to say that they are not distinguishable, but they require close scrutiny to distinguish them from the scorpions which exist at the present day.

More than that. At the very bottom of the Silurian series, in what is by some authorities termed the Cambrian formation, where all signs of life appear to be dying out—even there, among the few and scanty animal remains which exist, we find species of molluscous animals which are so closely allied to existing forms that at one time they were grouped under the same generic name. I refer to the well-known *Lingula* of the *Lingula* flags, lately, in consequence of some slight differences, placed in the new genus *Lingulella.* Practically it belongs to the same great generic group as the *Lingula*, which you will find at the present day upon the shores of Australia. And the same thing is exemplified if we turn to certain great periods of the earth's history—as, for example, throughout the whole of the Mesozoic period. There are groups of reptiles which begin shortly after the commencement of this period, as the *Ichthyosauria* and the *Plesiosauria*, and they abound in vast numbers. They disappear with the chalk, and throughout the whole of that great series of rocks they present no important modifications. Facts of this kind are undoubtedly fatal to any form of the doctrine of evolution, which necessitates the supposition that there is an intrinsic necessity on the part of animal forms which once come into existence to undergo modifica-

tion; and they are still more distinctly opposed to any view which should lead to the belief that the modification in different types of animal or vegetable life goes on equally and evenly. The facts, as I have placed them before you, would obviously contradict directly any such form of the hypothesis of evolution as laid down in these two postulates.

Now, the service that has been rendered by Mr. Darwin in the doctrine of evolution in general is this: that he has shown that there are two great factors in the process of evolution: one of them is the tendency to vary, the existence of which may be proved by observation in all living forms; the other is the influence of surrounding conditions upon what I may call the parent form and the variations which are thus evolved from it. The cause of the production of variations is a matter not at all properly understood at present. Whether it depends upon some intricate machinery—if I may use the phrase—of the animal form itself, or whether it arises through the influence of conditions upon that form, is not certain, and the question may for the present be left open. But the important point is the tendency to the production of variations; then, whether the variations which are produced shall survive and supplant the parent, or whether the parent form shall survive and supplant the variations, is a matter which depends entirely on surrounding conditions. If the surrounding conditions are such that the parent form is more competent to deal with them and flourish in them than the derived forms, then, in the struggle for existence, the parent form will maintain itself and the derived forms will be exterminated. But if, on the contrary, the conditions are such as to be better for the derived than for the parent form, the parent form will be extirpated and the derived form will take its place.

In the first case, there will be no progression, no advance of type, through any imaginable series of ages; in the second place, there will be modification and change of form. Thus the existence of these persistent types of life is no obstacle in the way of the theory of evolution at all. Take the case of the scorpions to which I have just referred. No doubt, since the Carboniferous epoch conditions have existed such as existed when the scorpions of that epoch flourished, in which they find themselves better off, more competent to deal with the difficulties in their way than any kind of variation from the scorpion type; and for that reason the scorpion has persisted, and has not been supplanted by any other form. And there is no reason in the nature of things why, as long as this world exists, if there be conditions more favorable to scorpions than any variation which may arise from them, these forms of life should not persist.

Therefore, this objection is no objection at all. The facts of this character—and they are numerous—belong to that class of evidence which I have called indifferent. That is to say, they may afford no

direct support to the doctrine of evolution, but they are perfectly capable of being interpreted in consistency with it. There is another order of facts of the same kind, and susceptible of the same interpretation. The great group of *Lizards*, which abound so much at the present day, extends through the whole series of formations as far back as what is called the Permian epoch, which is represented by the strata lying just above the coal. These Permian lizards differ astonishingly little from the lizards which exist at the present day. Comparing the amount of difference between these Permian lizards and the lizards of the present day with the prodigious lapse of time between the Permian epoch and the present age, it may be said that there has been no appreciable change.

But when you carry your researches farther back in time you find no trace whatever of lizards nor of any true reptile whatever in the whole mass of formations beneath the Permian. Now, it is perfectly clear that if our existing paleontological collections, our existing species of stratified rock, exhaust the whole series of events which have ever taken place upon the surface of the globe, such a fact as this directly contravenes the whole theory of evolution, because this theory postulates that the existence of every form must have been preceded by that of some form comparatively little different from it. Here, however, we have to take into consideration that important fact so well insisted upon by Lyell and Darwin—the imperfection of the geological record. It can be demonstrated as a matter of fact that the geological record must be incomplete, that it can only preserve remains found in certain favorable localities and under particular conditions; that it must be destroyed by processes of denudation, and obliterated by processes of metamorphosis—by which I mean that beds of rock of any thickness crammed full of organic remains may yet, either by the percolation of water through them or the influence of subterranean heat (if they descend far enough toward the centre of the earth), lose all trace of these remains, and present the appearance of beds of rock formed under conditions in which there was no trace of living forms. Such metamorphic rocks occur in formations of all ages, and we know with perfect certainty when they do appear that they have contained organic remains, and that those remains have been absolutely obliterated.

I insist upon the defects of the geological record the more because those who have not attended to these matters are apt to say to us, "It is all very well, but, when you get into difficulty with your theory of evolution, you appeal to the incompleteness and the imperfection of the geological record;" and I want to make it perfectly clear to you that that imperfection is a vast fact which must be taken into account in all our speculations, or we shall constantly be going wrong.

You will all see that singular series of tracks which is copied of

its natural size in the large diagram hanging up here, which I owe to the kindness of my friend Prof. Marsh, with whom I had the opportunity recently of visiting the precise locality in Massachusetts in which these tracks occur. I am, therefore, able to give you my own testimony, if needed, that they accurately represent the state of

FIG. 1.—TRACKS OF BRONTOZOUM.

things which we saw. The valley of the Connecticut is classical ground for the geologist. It contains great beds of sandstone, covering many square miles, and which present this peculiarity, that they have evidently formed a part of an ancient sea-shore, or, it may be, lake-shore, and that they have been sufficiently soft for a certain period of time to receive the impressions of whatever animals walked over them, and to preserve them afterward in exactly the same way, as such impressions are at this very moment preserved on the shores of the bay of Fundy and elsewhere. We have there the tracks of some gigantic animal (pointing to the diagram), which walked on its hind-legs. You see the series of marks made alternately by the right foot and by the left foot; so that from one impression to the other of the three-toed foot on the same side is one stride, and that stride, as we measured it, is six feet nine inches. I leave you, therefore, to form an impression of the magnitude of the creature which must have walked along the ancient shore, and which made these impressions.

Now, of such impressions there are untold thousands upon these shores. Fifty or sixty different kinds have been discovered, and they cover vast areas. But up to this present time not a bone, not a fragment, of any one of the great creatures which certainly made these impressions has been found; and the only skeleton which has been met with in all these deposits to the present day—though they have been carefully hunted over—is one fragmentary skeleton of one of the smaller forms. What has become of all these bones? You see we are not dealing with little creatures, but animals that make a step of six feet nine inches; and their remains must have been left somewhere. The probability is, that they have been dissolved away, and absolutely lost.

I have had occasion to work at series of fossil remains of which there was nothing whatever except the casts of the bones, the solid material of the bone having been dissolved out by percolating water. It was a chance in this case that the sandstone happened to be of such a constitution as to set, and to allow the bones to be afterward dissolved out, leaving cavities of the exact shape of the bones.

Had that constitution been other than what it was, the bones would have been dissolved, the beds of sandstone would have fallen together, become one mass, and not the slightest indication that the animal had existed would have been discovered.

I know of no more striking evidence than this fact affords, of the caution which should be used in drawing the conclusion, from the absence of organic remains in a deposit, that animals did not exist at the time it was formed. I believe that, having the right understanding of the doctrine of evolution on the one hand, and having a just estimation of the importance of the imperfection of the geological record on the other, all difficulty from the kind of evidence to which I have adverted is removed; and we are justified in believing that all such cases are examples of what I have designated negative or indifferent evidence—that is to say, they in no way directly advance the theory of evolution, but they are no obstacle in the way of our belief in the doctrine.

I now pass on to the consideration of those cases which are not—for reasons which I will point out to you by-and-by—demonstrative of the truth of evolution, but which are such as must exist if evolution be true, and which therefore are, upon the whole, strongly in favor of the doctrine. If the doctrine of evolution be true, it follows that, however diverse the different groups of animals and of plants may be, they must have all, at one time or other, been connected by gradational forms; so that, from the highest animals, whatever they may be, down to the lowest speck of gelatinous matter in which life can be manifested, there must be a sure and progressive body of evidence—a series of gradations by which you could pass from one end of the series to the other. Undoubtedly that is a necessary postulate of the doctrine of evolution. But, when we look upon animated Nature as it at present exists, we find something totally different from this. We find that animals and plants fall into groups, the different members of which are pretty closely allied together, but which are separated by great breaks or intervals from other groups. And we cannot at present find any intermediate forms which bridge over these gaps or intervals. To illustrate what I mean: Let me call your attention to those vertebrate animals which are most familiar to you, such as mammals, and birds, and reptiles. At the present day these groups of animals are perfectly well defined from one another. We know of no animal now living which in any sense is intermediate between the mammal and the bird, or between the bird and reptile; but, on the contrary, there are actually some very distinct and anatomical peculiarities, well-defined marks, by which the mammal is separated from the bird, and the bird from the reptile. The distinctions are apparent and striking if you compare the definitions of these great groups as they now exist. At the present day there are numerous forms of what we may call broadly the pig tribe,

and many varieties of ruminants. These latter have their definite characteristics, and the former have their distinguishing peculiarities. But there is nothing that fills up the gap between the ruminants and the pig tribe. The two are distinct. So also is this the case between the groups of another class—reptiles. We have crocodiles, lizards, snakes, and tortoises, and yet there is nothing—no connecting link—between the crocodile and lizard, or between the lizard and snake, or between the snake and the crocodile, or between any two of these groups. They are separated by absolute breaks. If, then, it could be shown that this state of things was from the beginning—had always existed—it would be fatal to the doctrine of evolution. If the intermediate gradations which the doctrine of evolution postulates must have existed between these groups—if they are not to be found anywhere in the records of the past history of the globe—all that is so far a strong and weighty argument against evolution; while, on the other hand, if such intermediate forms are to be found, that is so much to the good of evolution, although, for the reason which I will put before you by-and-by, we must be cautious in assuming such facts as proofs of the theory.

It is a very remarkable fact that, from the commencement of the serious study of paleontology, from the time in fact when Cuvier made his brilliant researches upon the fossil remains of animals found in the quarries of Montmartre, Paleontology has shown what she was going to do in this matter, and what kind of evidence it lay in her power to produce.

I said just now that at the present day the group of pig-like animals and the group of ruminants are entirely distinct; but one of the first of Cuvier's discoveries was an animal which he called the *Anoplotherium*, and which he showed to be, in a great many important respects, intermediate in its character between the pigs on the one hand and the ruminants on the other; that, in fact, research into the history of the past did so far—and to the extent which Cuvier indicated—tend to fill up the breach between the group of ruminants and the group of pigs. All subsequent research has also tended in this direction; and at the present day the investigations of such men as Rütimeyer and Gaudry have tended to fill up and connect, more and more, the gaps in our existing series of mammals. But I think it may have an especial interest if—instead of dealing with these cases, which would require a great deal of tedious osteological detail—I take the case of birds and reptiles—which groups, at the present day, are so clearly distinguished from one another that there are perhaps no classes of animals which in popular apprehension are more completely separated. Birds, as you are aware, are covered with feathers; they are provided with wings; they are specially and peculiarly modified as to their anterior extremities; and they walk perpendicularly upon two legs; and those limbs, when they are considered anatomically,

present a great number of exceedingly remarkable peculiarities, to which I may have occasion to advert incidentally as I go on, but which are not met with even approximately in any existing forms of reptiles. On the other hand, reptiles, if they have a covering at all, have a covering of scales or bony plates. They possess no wings; they are not volatile, and they have no such modification of the limbs as we find in birds. It is impossible to imagine any two groups apparently more definitely and distinctly separated. As we trace the history of birds back in time, we find their remains abundant in the tertiary rocks throughout their whole extent, but, so far as our present knowledge goes, the birds of the tertiary rocks retain the same essential character as the birds of the present day—that is to say, the tertiary bird comes within the definition of our existing birds, and are as much separated from reptiles as our existing birds are. A few years ago no remains of birds had been found below the tertiary rocks, and I am not sure but that some persons were prepared to

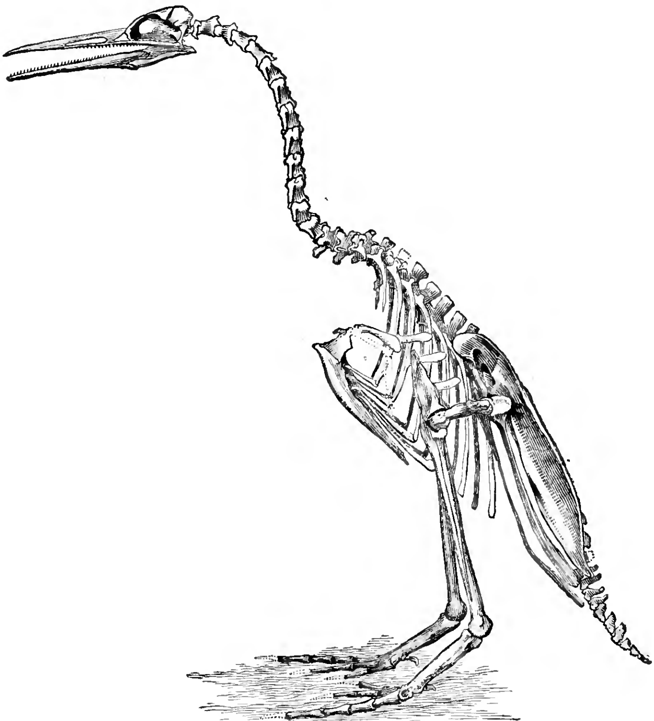


FIG. 2.—HESPERORNIS REGALIS. (Marsh.)

demonstrate that they could not have existed at an earlier period. But in the last few years such remains have been discovered in England, though, unfortunately, in a very imperfect condition. In your

country the development of cretaceous rocks is enormous; the conditions under which the later cretaceous strata have been deposited are highly favorable to the preservation of organic remains, and the researches full of labor and toil, which have been carried on by Prof. Marsh in these Western cretaceous rocks, have rewarded him with the discovery of forms of birds of which we had hitherto no conception. By his kindness, I am enabled to place before you a restoration of one of these extraordinary birds, every part of which can be thor-

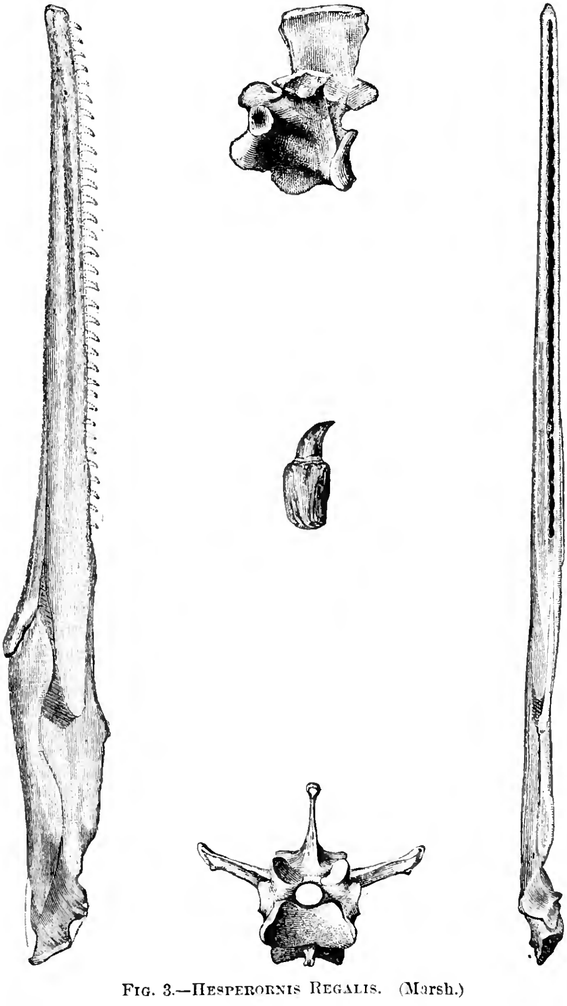


Fig. 3.—Hesperornis Regalis. (Marsh.)

oughly justified. The remains exist in the greatest beauty in his collection. This *Hesperornis* stood about six feet high, and in a great many respects is astonishingly like an existing diver or grebe, so like

it indeed that, had this skeleton been found in a museum, I suppose—if the head had not been known—it would have been placed in the same general group as the divers and grebes of the present day. But this bird differs from all existing birds, and so far resembles reptiles in one important particular that it is provided with teeth. These

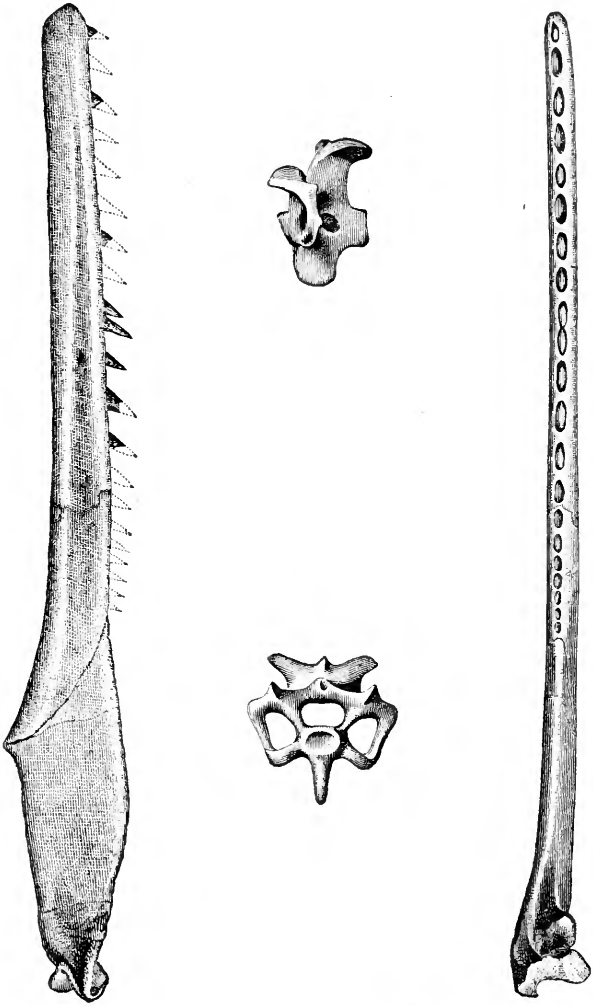


FIG. 4.—ICHTHYORNIS DISPAR. (Marsh.)

long jaws are beset by teeth, as in this diagram, in which one of the teeth is represented separately. In possessing true teeth, the *Hesperornis* differs entirely from any existing bird, and in view of the characteristics of this bird we are obliged to modify the definition of the class of birds and reptiles. Before the discovery of a creature such

as this, it might have been said that birds were characterized by the absence of teeth; but the discovery of a bird that had teeth shows at once that there were ancient birds that, in that particular respect, approached reptiles more nearly than any existing bird does.

The same rocks have yielded another bird (*Ichthyornis*), which also has teeth in its jaws, the teeth in this case being situated in distinct sockets, while those of *Hesperornis* were not so lodged. The latter also had very small wings, while *Ichthyornis* has strong wings. *Ichthyornis* also differed in the fact that the joints of its backbone—its vertebræ—had not the peculiar character that the vertebræ of existing birds have, but were concave at each end. This discovery leads us to make another modification in the definition of the group of birds, and to part with another of the characters by which they are distinguished from reptiles. We know nothing whatever of birds older than these until we come down to the Jurassic period, and from rocks of that age we have a single bird which was first made known by the finding of a fossil feather. It was thought wonderful that such a perishable thing as a feather should be discovered and nothing more, and so it was; and for a long time nothing was known of this bird except its feather. But, by-and-by one solitary specimen was discovered, which is now in the British Museum. That solitary specimen is unfortunately devoid of its head; but there is this wonderful peculiarity about the creature that, so far as its feet are known, it has all the characters of a bird, all those peculiarities by which a bird is distinguished from a reptile. Nevertheless, in other respects, it is unlike a bird and like a reptile. There is a long series of caudal vertebræ. The wing differs in some very remarkable respects from the structure it presents in a true bird. In a true bird the wing answers to these three fingers—the thumb and two fingers of my hand—the metacarpal bones are fused together into one mass—and the whole apparatus except the thumb is bound up in a sheath of integument, and the edge of the hand carries the principal quill-feathers. It is in that way that the bird's wing becomes an instrument of flight. In the *Archæopteryx*, the upper-arm bone is like that of a bird; these two forearm bones are more or less like those of a bird, but the fingers are not bound together—they are free, and they are all terminated by strong claws, not like such as are sometimes found in birds, but by such as reptiles possess, so that in the *Archæopteryx* you have an animal which, to a certain extent, occupies a midway place between a bird and a reptile. It is a bird so far as its foot and sundry other parts of its skeleton are concerned; it is essentially and thoroughly a bird in the fact that it possesses feathers, but it is much more properly a reptile in the fact that what represents the hand has separate bones resembling those which terminate the fore-limb of a reptile. Moreover, it had a long tail with a fringe of feathers on each side. All these cases, so far as

they go, you will observe are in favor of evolution to this extent, that they show that in former periods of the world's history creatures existed which overstepped the bounds of all existing classes and groups, and tended to fill up the intervals which at present exist between them. But we can go further than this. It is possible to fill up the interval between birds and reptiles in a much more striking manner. I do not think that this is to be done by looking upon what are called the *Pterodactyls* as the intermediate form between

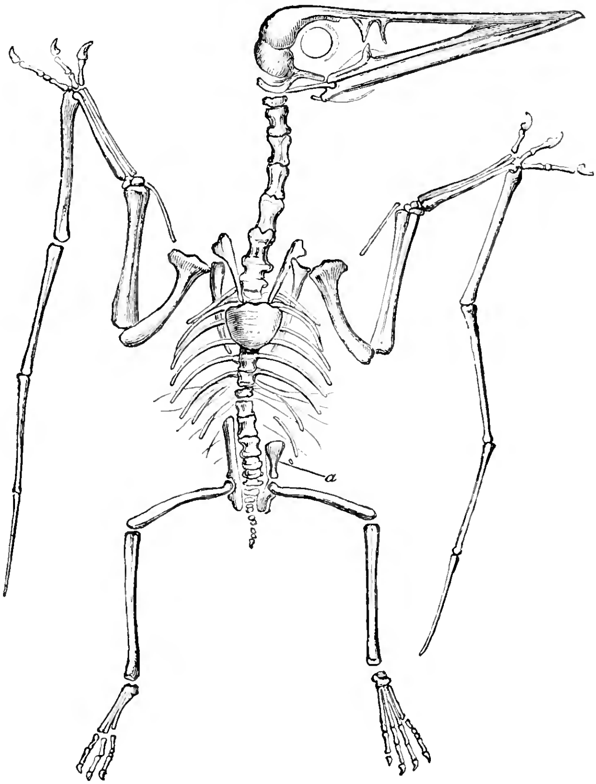


FIG. 5.—PTERODACTYLUS SPECTABILIS. (Von Meyer.)

birds and reptiles. Throughout the whole series of the mesozoic rocks we meet with some exceedingly remarkable flying creatures, some of which attain a great size, their wings having a span of eighteen or twenty feet or more, and these are known as *Pterosauria*, or *Pterodactyls.* We find these with a bird-like head and neck, with a vertebral column sometimes terminated by a short and sometimes by a long tail, and in which the bones of the skeleton present one of the peculiarities which are often considered to be most characteristic of birds—that of having pneumatic cavities, which make

the creature specifically light in its flight. Like a bird, this creature has a largish breastbone, but from that point onward, so far as I can see, special, particular resemblances end, and a careful examination of the fore-limbs shows you that they are not birds' wings; they are something totally different from a bird's wings. And then, again (pointing to a chart), those are not a bird's posterior extremities, but are rather a reptilian's hind-limbs. The vertebræ present nothing that I need dwell upon, but the bones of the hand are very wonderful.

There are four fingers represented. These four fingers are large, and three of them—these, which answer to these three in my hands—are terminated by claws, while the fourth is enormously prolonged into a great jointed style. You see at once from what I have stated about a bird's wing that there could be nothing more unlike a bird's wing than this is. It was concluded by general reasoning that this finger was made to support a great web like a bat's wing. Specimens now exist showing that this was really the case, that this creature was devoid of feathers, but the fingers supported a vast web like a bat's wing, and there can be no doubt that this ancient reptile flew after the fashion of a bat. Thus, though the pterodactyl is a flying reptile, although it presents some points of similarity to birds, yet is it so different from them that I do not think that we have any right to regard it as one of the forms intermediate between the reptile and the bird. Such intermediate forms are to be found, however, by looking in a different direction. Through the whole series of mesozoic rocks there occur reptiles, some of which are of gigantic dimensions; in fact, they are reckoned among the largest of terrestrial animals. Some of them are forty and fifty, possibly more, feet long. Such are the *Iguanodon*, the *Megalosaurus*, and a number of others, with the names of which I will not trouble you. There are great diversities of structure among these great reptiles. Some of them resemble lizards in the proportions of their limbs, and have evidently walked on all-fours, in that respect resembling the existing crocodile; but in others you can trace a series of modifications in virtue of which the hind-limbs at length completely assumed the character of a bird's hind-limbs. I here indicate (pointing to a diagram) the hind limb of a crocodile, showing the bones of the hind-limbs and of the pelvis. These are the haunch-bones; these are the two leg-bones. Then comes the division of the foot which we call the tarsus, in which the component bones are separate and distinct from one another, from the bones of the leg and from those of the metatarsus. Then come the four toes, which alone exist in the hind-feet of the crocodile, and which are separate and distinct. The foot is flat on the ground, so that the legs spread out and the weight of the body hangs clumsily between them. Contrast this with what we find in the bird—the haunch-bone here is immensely elongated, and the joints of the

back-bone, between the two haunch-bones, are united so as to form a solid support upon which the weight of the body rests. Then the thigh-bone becomes very short, and has a back ridge upon its outer articular surface. At the lower end the ridge fits in between the upper extremity of the small bone of the leg, near to the great bone,

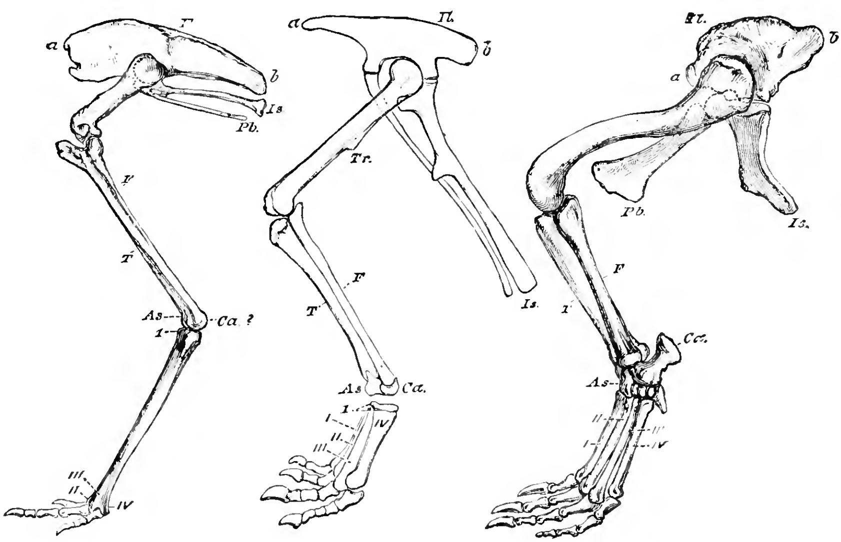


Fig. 6.—Bird. Dinosaur. Crocodile.

and makes a kind of spring-joint. The small bone of the leg is quite large above, and becomes rudimentary below. It runs out into a style, instead of being long and large, as it is in the case of the crocodile. Then, when you come to the bones of the foot, you find there are no separate bones such as you have here, but the end of the tibia, or large bone of the leg, appears to end in a kind of pulley, a single bone follows the tibia and to the trifurcated extremity of this bone. Upon the extremity of that bone are attached three toes. It is obvious that the contrast between the crocodile's leg on the one hand, and the bird's leg on the other, is very striking. But this interval is completely filled up when you study the character of the hinder extremities in those ancient reptiles which are called the *Dinosauria*. In some of these the bones of the pelvis, and those of the hind-limb, become extraordinarily similar to those of birds, especially to those of young or fœtal birds. Furthermore, in some of these reptiles, the fore-limbs become smaller and smaller, and thus the suspicion naturally arises that they may have assumed the erect position. That view was entertained by Mantel, and was also demonstrated to be probable by your own distinguished anatomist, Leidy, but the discoveries of late years show that in some of these forms the

fact was actually so; that reptiles once existed which walked upon their hind-legs as birds now do. The diagram is a faithful and accurate representation of an existing fossil except for this, that, whereas in the existing fossil the bones are twisted about and out of place, I

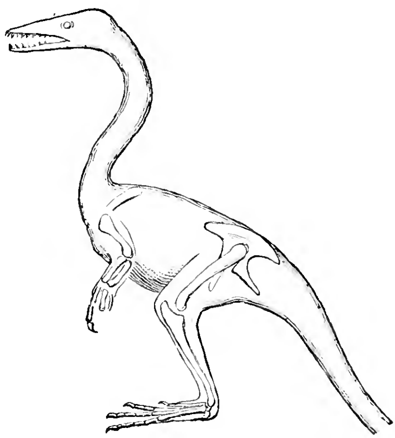


FIG. 7.—COMPSOGNATHUS LONGIPES. (Wagner.)

have put them here in the position that they must have had in nature. You see a creature with a long neck and bird-like head, with very small anterior extremities, and that *compsognathous* creature must assuredly have walked about upon its hind-legs, bird-fashion. Add to this feathers, and the transition would be complete. Now to define it: The possession of teeth would, as we see, not separate this animal from the class of birds we have. We have had to stretch the class of birds so as to include birds possessed of teeth, and, so far as the character of the skeleton goes, we may fairly say that there needs here little more than the addition of feathers—and whether this creature had them or not we don't know—to convert it into a bird.

I have said that there can be no question, from their anatomical structure, that these animals walked upon their hind-legs, and, in fact, there are to be found in the Wealden strata of England gigantic footsteps arranged in order like these of the *Brontozoum*, and which there can be no reasonable doubt were made by *Dinosauria*, the remains of which were found in the same rock. And, knowing that reptiles that walked upon their legs and shared many of the anatomical characters of birds did once exist, it becomes a very important question whether those tracks in Massachusetts—to which I referred just now, and which formerly used to be unhesitatingly ascribed to birds—may not all have been made either by reptiles similar to the *Dinosauria*, or whether, if we could get hold of the skeleton which made these

tracks, some of which are marvelously like bird's tracks, we should not come upon exactly that series of transitions by which in former days the reptile was connected with the bird.

I don't think, ladies and gentlemen, that I need insist upon the value of evidence of this kind. You will observe that, although it does not prove that birds have originated from reptiles by the gradual modification of the ordinary reptile into a dinosaurian form, and so into a bird, yet it does show that such a process may possibly have taken place, and it does show that, in former times, there existed creatures which filled up one of the largest gaps in existing animate nature, and that was exactly the kind of evidence which I stated to you in starting we are bound to meet with in rocks if the hypothesis of evolution be correct.

In my third and last lecture I will take up what I venture to call the demonstrative evidence of evolution.

ON VARIATION IN THE MOTHS.

By AUG. R. GROTE, A. M.

THERE are a large number of different kinds of moths, inhabiting North America and Europe, which entomologists have classified under the technical family term, *Noctuæ.* Of this family, 1,028 different species have been catalogued as European. There being very many students, and a sufficient time having elapsed to secure a thorough collecting throughout the territory, this number may be taken as sufficiently corresponding with the actual representation of the family in Europe. In North America nearly 1,200 species are now catalogued,[1] but, since much of our territory remains to be explored in this respect, we may expect considerable additions to the number of known *Noctuæ* inhabiting our continent. The greater number of the species may be easily distinguished on comparison, the American from the European. There are, however, certain American species which differ but very slightly from certain European, and hence are generally called "representative species," or "species of replacement." For instance, *Apatela occidentalis* (G. and R.) "represents" the European *Apatela psi* (Linn.); *Agrotis Normaniana* (Grote), the European *Agrotis triangulum; Calocampa nupera* (Lintner), the European *Calocampa vetusta; Catocala relicta* (Walk.), the European *Catocala fraxini*, etc.

Although the number of such species appears relatively small,

[1] "List of the Noctuidæ of North America, 1875-'76." Buffalo, Reinecke & Zesch.

it is probably in reality larger than as yet suspected. For even the species acknowledged to occupy this relationship to each other exhibit quite different degrees of resemblance. I say "relationship," for we must reasonably conclude that this resemblance is not accidental or meaningless. It must indicate that both the European and American species are derived from a common stock. More than two years ago, I suggested that the faunæ had become separated through the physical action of the glacial epoch, showing that from the present distribution of species, and their degree of resemblance, no other hypothesis would explain all the facts in the case so satisfactorily. For we have to account, first, for the occurrence of nearly-related forms in localities as widely separated, geographically, as Texas and Germany; and then, again, for the occurrence, within our territory, of nearly-related species on the Alpine summits of Mount Washington and the distant arctic regions. The method of probable distribution of these latter species, through the action of the retreating ice, I have explained in the *Américan Naturalist* for March of this year.

In studying specimens of these related American and European species of *Noctuæ*, some new light bearing upon the question of their differences is attempted to be thrown in the present paper. I have endeavored to localize these differences upon some portion of the insect. In all the cases I have been able to investigate, these differences are expressed on the upper surface of the body and wings, and principally on the upper surface of the front pair of wings. Here it is that the first variations, which now have grown into specific differences, were probably expressed. And the reason for this seems to be, that this portion of the body is that usually exposed to the light and the action of external influences. The moths, during the daytime, rest with the front-wings dependent over the hind-wings, and nearly covering the body. While in the American and European related species the differences which lead us to call them distinct "species" are located on the front-wings chiefly, the under surfaces of both wings remain exceedingly similar in the contrasted forms. This is the portion which in the day time (the period of inaction for moths) is applied to the surface against which the insect rests, and is entirely shielded from exposure. Take, for instance, the European *Catocala fraxini* and the American *Catocala relicta*. The ground-color of the American species above and below is a bright, clear white. Now, beneath, both species show this color, but the upper surface of the fore-wings, in the European species, is obscured by an evenly-distributed admixture of blackish scales, so that the wings appear of a uniform obscure gray. The hind-wings, in the European species, are crossed by a band of bluish scales; in the American, this band is white, while I have recently detected a slight powdered edging of blue scales, difficult to perceive, and apparently hitherto unnoticed. The principal difference in ornamentation is, again, to be found on the

upper surface of the fore-wings. It lies in the course and shape of the transverse posterior line—a line which is a general feature of ornamentation throughout this group of insects.

This position might be sustained by parallel facts, but the limit of this article does not allow of their being presented. It remains to see what light these observations throw upon the origin of all these different kinds of moths. They seem to me to point to a method of variation in this group, and to a reason for its display. And, if we can apply these observations to particular instances, they may lead to a better understanding of the value of these specific forms, by allowing us to appreciate with more exactness the amount of differentiation they have undergone in the lapse of time. In a wider sense, we may attempt a classification by the ornamentation and coloration in the moths based on method, and such studies cannot fail to lend fresh interest to the barren but necessary work of describing the different species or forms. It seems to me, also, that these observations vindicate the importance of studying the characters of color and pattern in the group, and are, perhaps, a criticism on the remarks of those writers who purposely allow these no higher value than the subordinate one of dividing their material into "species" in their collections. In fact, these characters may give us a clew to the genealogy of the group, and seem to be of sufficient importance to be noted in descriptions of genera.

THE CONSTANCY OF MOTION.

By GEORGE ILES.

THE conservation of energy, as treated in the most recent work of authority on the subject, Prof. Balfour Stewart's, published in the "International Scientific Series," regards energy as divisible into two classes, actual and potential: actual energy, as in the case of a rushing stream of water, or a radiant and contracting mass of molten iron; and potential energy, where, for instance, a stone is at a height and may fall, or where a spring is tightly coiled and may unwind.

Prof. Stewart speaks the general opinion of modern physicists, Profs. Rankine, Tyndall, and others, when he states that, in cases of potential energy, the bodies endowed with it are absolutely at rest, and that the motion exhausted in storing up such energy is represented by a mere advantage of position, which, when utilized, yields in actual, palpable motion the energy which has lain completely quiescent, as when the stone falls to the earth, or the freed spring uncoils.

This division of energy into actual and potential seems to me to

be defective. It prevents the direct comprehension in the mind of energy as being motion and nothing else; it leaves unexplained how a body perfectly at rest can come to move; and further implies the dissipation of energy (which I have treated in a previous number of this journal) in a new phase, for, if all the actual energy in the universe were to become potential, all the real and positive motions which constitute life might indefinitely cease.

Let us examine, then, some cases of "potential" energy, and see if they be not actual, although under a disguise; so that the present definition of the conservation of energy may be replaced by the more intelligible statement that motion is constant; that it is never abolished for a time, nor absolutely suspended, all appearances to the contrary notwithstanding; and that so, all cases of energy are dynamic, and no part of them static, as now currently held.

For matter seemingly at rest may contain within itself motions as real as those to which at another time it openly gives rise, when it radiates heat or attracts by magnetism.

First of all, then, let us consider the case of a stone at a height, say on the brow of a cliff, capable of falling at any time when slightly pushed.

Gravity is the one force, of all the forms of energy, whose relations with others it is most difficult to imagine.

Other forces affect each other most palpably: magnetism forsakes a magnet when it is made white hot; chemical affinity is most sensitive to variations of temperature, and even in some cases to mechanical tremor; the transmission of electricity is favored by the cooling of a conductor, and so on.

Otherwise is it with gravity: a given mass of matter, however mechanically moved, electrified, magnetized, heated, or subjected to chemical changes, at the same point on the earth's surface, always weighs the same.

The only force with which gravity has any analogy is magnetism; and were magnetism always attractive, instead of polar, with equal opposite manifestations of attraction and repulsion, the analogy would be a strong one.

Let us, however, work out what analogy there is, and we may find that as the subtile movements of light were made plain by the study of the grosser movements of sound in air, so may the long-hidden laws of gravity be revealed in part, by tracing the similitude existing between their effects and those of common magnetism.

Both forces obey the law of squares: according to that law, they diminish as we recede from their centres of attraction. And what is very suggestive is, that, as their appetites are satisfied, they decrease in exactly the same ratio.

Two small magnets at a great distance from each other (so as to be practically out of the range of each other's influence), having each

a force equal to 1, when permitted to unite, have together a force less than 2; and this because work can be done by their attraction mechanically, or may appear as heat; and of course this must diminish their original stock of energy.

Precisely so with gravity. Suppose, for simplicity's sake, the radius of the earth to be 4,000 miles. Let us then imagine a stone of four tons lifted from the earth's surface to a distance of 4,001 miles; it would there weigh one ton—very nearly. Were such a mass to fall it would pass through 4,001 miles of space, and yield corresponding work.

Now let us further imagine a world, concentric with our present one, to be made up by the union of the earth with seven other such planets, and let us leave out of the question any possible condensation in the matter of this new world. Then supposing the stone to have resumed its former position in space, if gravity were allowed to act again, it could only do so through one mile, instead of 4,001 miles as before.

And mark how the geometrical necessities of enlargement lessen the working power of a mass attracting by gravity; for a stone weighing four tons on our present globe would only weigh twice as much on a sphere containing eight times the matter.

In the latter case, the surface would be twice as distant from the centre as in the former; for the attraction diminishes as the square of the distance of surface from the centre. Therefore the 8 times increased bulk has to be divided by 4, the square of the doubled radius.

Thus the weight of a definite mass on any celestial body varies as the density of the body and as the radius of it.

One of our pound-weights taken to the sun would there weigh 27 pounds, the sun's radius being about 110 times that of the earth, but its density only about one-fourth as great; while its bulk exceeds that of our planet by as much as 1,252,000 times.

If we now attentively observe the energy of a magnet in its usual genesis, we may learn somewhat, not only of gravity, but of attraction in general. The most convenient way to make magnets is by the use of an electric coil. A piece of properly-tempered steel is inserted in a helix of copper wire, through which a current circulates proceeding from the mechanical motion of a steam-engine, converted into electricity by suitable apparatus.

Other methods of magnetization there are, but none so directly instructive as this; here we have the visible, palpable motion of heavy wheels disappearing, and the chief result is the attractive force developed in the steel. The conviction dawns upon us that the motion of the wheels has been taken up by the molecules of the bar, that the steel has now internal movements which before it had not; and that these movements of its particles exist in full actuality, capable of doing tangible work when fitly permitted. Let us bring

a piece of iron or steel near to the magnet, and instantly it leaps toward it, confirming our conviction.

That a medium exists for the conveyance of such molecular motion, we are obliged to think; but what it is, or how it is affected, we cannot yet imagine. Thus much, however, is plain, that, as a medium purely, it can be no source of motion, so that the mere fact of distance between bodies can be no satisfactory explanation of attraction.

Attraction, then, wherever it appears, I believe to be due to contained motion in the particles of the bodies presenting it; which molecular motion is the equivalent of, and convertible into, the movement of masses as wholes.

Gravity, I venture to hold, is a force due to a distinct motion of the ultimate parts of matter, which has not yet been formulated. And, as the energy expended in sundering two united magnets reappears in the increase of their attractive powers, or the acceleration of such motion of their particles as constitutes magnetism, so the lifting of a stone from the earth would imply that the force consumed in so doing must take the form of a quickening in that motion of its particles which constitutes gravity. And we have seen how every successive act of obedience to both these forces of aggregation makes them weaker and weaker, as it reasonably should.

Therefore, I conclude that the energy of a stone at a height is not potential, but actual; that its value as a source of work, at any time, is represented by the swifter motion of its molecules as compared with those of a stone on the earth's surface; and that, as a stone falls, its internal motion takes the phase of mass motion.

This theory would lead us to suppose that the onward momentum of the planets, as they turn before the sun, is the expression of an equal internal gravitive motion of their ultimate parts, which exactly balances these mighty celestial revolutions.

The next case of "potential" energy to be inquired into is that of a coiled spring, which, in unwinding, may yield the force it took to coil it.

This case may be intelligibly explained on the same principle of the constancy of motion. The particles of a spring may be assumed to have a definite plane of molecular motion, which motion we shall presume is that due to temperature. In coiling, these planes are changed, and energy is required to do it; just as when a gyroscope-top is rapidly revolving in a certain fixed plane, it may, by a measurable effort, be made to revolve in a conical curve, with one end of its axis stationary, and the other describing a circle in space. And, as the gyroscope strongly tends to move in a uniform plane, and can do work in resuming such a plane, so I assume that the particles in a coiled spring have two similar motions, one of which is at any time available for tangible work when the spring is freed.

Yet another example. Let us take the case of a cylinder of compressed air which for years, tightly sealed, may serve as a store of force.

Prof. Clerk Maxwell explains how an ounce of air, in a closed and fragile jar, sustains the outside pressure of the atmosphere amounting to several tons; this he does by the theory that the ounce of air is made up of molecules which have so rapid a motion among themselves that they collide on the inside of the jar with as great a force as that of the atmospheric pressure externally.

This theory, now widely accepted, rests on the solid grounds of the measured velocity of air rushing into a vacuum, which is the same as that assumed for its internal motion; and further, on some observations of the diffusion of various gases into each other, which it would be out of place to detail here.

On the basis, then, of Prof. Maxwell's theory, we can believe that, in a cylinder of compressed air, the energy stored up exists in no merely "potential" form, but in the full actuality of the rapid motion of gaseous particles, which may take the shape of mass-motion when the piston is allowed to move outward.

An extension of the hypothesis that motion is continuous would lead to the inference that the so-called latent heat of water at 32° Fahr., as compared with ice at the same temperature, is due to the swifter movement of the molecules in the former case; and no facts are better known than that mechanical motion can become heat, and that heat turns ice into water.

Another implication of this theory is that atoms, as free hydrogen, oxygen, or carbon, are in exceedingly greater commotion than molecules, such as those of water or carbonic-acid gas. For the decomposition of such molecules may be effected by the exhaustion of mechanical motion, and I take it that the dynamic state of the products must balance this expenditure. What else can become of it?

The measure of the contained motion in two different atoms can be noted on their combining chemically, by the increase of temperature, which has its well-known mechanical equivalent.

The analogy between chemical units and small magnets is very close: as a magnet decreases in size, so, relatively thereto, does its attractive power increase; and, were we able to go on dividing until we came to a single atom of iron, we should doubtless have the magnetism merge into the equivalent phase of intense chemical affinity.

Without further illustration, then, of the principle set forth, I will say that, as in recent years we have had to familiarize ourselves with the idea that many forms of actual energy are impalpable, as the rays of light and the waves of sound, so now I think there are good grounds for extending our ideas so as to believe that all phases of "potential" energy are really actual; that, as we cannot but think

that only motion can breed motion, energy means motion; and that as such its amount is constant, and its presence, behind whatever veil, continuous; so that it is only properly divisible into two kinds, perceptible and imperceptible.

SKETCH OF PROFESSOR MAYER.

AMONG the younger physicists of the country who have done honor to American science by the interest and extent of their original researches, the subject of the present sketch, and of whom we give an excellent portrait this month, holds a distinguished place. Though now only in the prime of his manhood, he has already made many refined and elaborate experimental researches, by which he is widely and favorably known to men of science both in this country and in Europe.

Alfred Marshall Mayer was born in Baltimore, November 3, 1836. His grandfather, Christian Mayer, was descended from an ancient family in the city of Ulm, Würtemberg, and came to Baltimore when a young man. Here he made a large fortune in trade with India and Mexico. He was well known in his day for his liberal and elegant hospitality, his extensive reading, profound knowledge of mercantile law, and those marked social and gentlemanly traits that made him a delightful companion. His father was Charles F. Mayer, who was distinguished for his learning, eloquence, and extensive literary culture. He is the nephew of Brantz Mayer, a prominent writer, who is especially known by his various valuable works on Mexico, where he resided for a time as secretary of legation.

Prof. Mayer was partly educated at St. Mary's College, in Baltimore, which he left at the age of sixteen for a more practical sphere of study. He entered the workshop and draughting-room of a mechanical engineer, where he remained two years, acquiring a knowledge of the use of tools, mechanical drawing, the method of constructing machines, and careful mechanical manipulation. Subsequently, during two years, he cultivated analytical chemistry by thorough laboratory practice.

Prof. Mayer has occupied the chair of Physics, with Chemistry and Astronomy, in several colleges, as follows: University of Maryland, 1856–'58; Westminster College, Missouri, 1859–'61; Pennsylvania College, Gettysburg, 1865–'67; Lehigh University, Bethlehem, Pennsylvania, 1867–'70; and the Stevens Institute of Technology since 1871. In 1863–'64 he studied physics, mathematics, and physiology, in the University of Paris.

Prof. Mayer's first contribution to science was made in 1855, and

described in a paper in the *American Journal of Science and Arts*, entitled "A New Apparatus for the Determination of Carbonic Acid," which was republished in Germany. His second paper was on the estimation of weights of very small portions of matter, in which he showed that, by the deflections of fine glass fibres, we can weigh a particle of matter as small as the $\frac{1}{1000}$ of a milligramme. While at the Lehigh University, he designed and superintended the erection of an astronomical observatory, put together and adjusted the instruments, and made a series of observations on the planet Jupiter, which were republished in England. He was in charge of the party sent by the United States Government to observe the eclipse of the sun at Burlington, Iowa, August 7, 1869, and took forty-one perfect photographs of the eclipse with exposures lasting only the $\frac{1}{500}$ of a second.

While at the Lehigh University, Prof. Mayer contributed to the *American Journal of Science and Arts* and the *Journal of the Franklin Institute* various original contributions on the "Solar Protuberances," "Spectral Analysis of the Stars," "Physical Constitution of the Sun," "Electro-Magnetism," "Electric Conductivities," "On the Alleged Electro-Tonic State," "Magnetic Declination in Connection with the Aurora," "Photographing the Magnetic Spectra;" and at the Salem meeting of the American Association he read an instructive paper "On the Thermo-Dynamics of Waterfalls." He had taken the temperatures of the water at Trenton and Niagara before it leaps the cataract and after it strikes below. According to theory, when the falling motion is arrested, it is converted into heat, and should be shown in a rising temperature below. The observations indicated that the effects of evaporation and contact of the divided water with the air were greater than the impact in changing the temperature of the fallen water, so that it may be actually colder below than above. But on days when the air is saturated with moisture, and the temperatures of the water and air are about the same, results were obtained which show that the warming of the falling water conforms to Joule's law of the conversion of motion into heat.

Since entering upon his duties at the Stevens Institute of Technology, notwithstanding the labor of lecturing and teaching which the position involves, Prof. Mayer has conducted elaborate investigations in various branches of physics, which have given to science many new and important results. Among these may be mentioned researches in magnetism, heat, and especially "On the Effects of Magnetization in changing the Dimensions of Iron and Steel Bars," and "On the Isothermals of the Solar Disk." We cannot here give the particulars of these interesting inquiries, but must refer the reader to the memoirs in the scientific journals.

The line of investigation, however, to which Prof. Mayer has mainly devoted himself within the last few years is that of acoustics

in its various physical connections, and especially in relation to the theory of music. These researches are described in papers contained in the *American Journal of Science and Arts*, and several of his important conclusions have been incorporated in the English edition of Helmholtz's "Sensations of Tone as a Physiological Basis for a Theory of Music." Mr. Alexander J. Ellis, F. R. S. (the translator of the above work), has also recently published a lecture which he delivered before the London Musical Association, on the application of Prof. Mayer's discoveries to the elucidation of the fundamental principles of musical harmony.

The chief claims of Prof. Mayer in regard to his recent acoustical results may be concisely summed up as follows:

1. He discovered that, by using the phenomena of sympathetic vibration, one can show that the translation of a vibrating body causes it to give sonorous waves, differing in length from those produced by the same vibrating body when stationary.

2. He first succeeded in actually detecting the different phases of vibration *in the air surrounding a sounding body*, and thereby measured the lengths of its waves; and first experimentally explored in the free air the exact form of any wave-surface; and he has determined the forms of these envelopes around a sounding body with as much facility as one can obtain the form of the surface of a palpable body *in the dark*.

3. He devised a simple and accurate method of measuring the wave-lengths of sound in air and in gases, and was the first to measure with precision the relative intensities of sounds by means of manometric flames.

4. He first approximately determined the mechanical equivalent of an aërial sonorous vibration.

5. He obtained in an experiment all the conditions required in "Fourier's theorem," and thus first gave an exact experimental confirmation of it.

6. He has devised and used *five* new methods of sonorous analysis for the decomposition of a compound sound into its elementary simple tones. He also first, by means of a rotating disk, reproduced the vibratory motions of a molecule of air, when it is animated with the resultant action of the six elementary vibrations forming a musical note.

7. He first discovered, by delicate experiment, that the fibrils of the antennæ of the male mosquito vibrate sympathetically to notes which have the range of pitch of the sounds given out by the female mosquito. He also showed first how an insect may determine the direction of sounds by means of his antennæ.

8. He discovered that the terminal auditory nerve-fibrils vibrate half as often in a given time as the membrane of the tympanum and

the ossicles of the ear, and proposed on these facts a new hypothesis of the mode of audition.

9. He first discovered the law connecting the pitch of a sound with the time that the sensation of the sound endures after the air has ceased to vibrate the tympanic membrane. This law rendered the qualitative results of Helmholtz quantitative; and in the third edition of Helmholtz's "Tonempfindungen" Mr. Alexander J. Ellis, as noted above, has extensively used this law as the only basis for reaching exact quantitative results in the fundamental phenomena of musical harmony. This law Prof. Mayer has applied extensively to the elucidation of the fundamental facts of harmony, and to the explanation of many obscure phenomena in the physiology of hearing.

10. He discovered that sonorous sensations interfere with one another, and that, although a low sound may entirely obliterate the sensation of a sound *higher* in pitch, yet a sound cannot in the slightest obliterate the sensation of another sound *lower* than it in pitch. He has made applications of these discoveries in showing that a radical change is required in the usual method of conducting orchestral music, and in a new method of determining the relative intensities of sounds.

11. He has determined with great precision the laws of the vibrations of tuning-forks, especially in the direction of the bearing of these laws on the action of chronoscopes used in determining the velocities of projectiles. He first accurately gave the correction to be applied in all such determination on account of the different temperatures of the forks.

Besides these difficult and delicate original investigations, Prof. Mayer has contributed numerous articles to Appletons' and Johnson's "Cyclopædias" in his more especial lines of inquiry, and has written much for various popular publications. He was one of the editors of the *American Journal of Science and Arts*, but reluctantly gave up its duties in 1873 on account of weakness of sight. He then suspended work, and went to England for a vacation, where he was cordially received and kindly entertained by his brethren of the various scientific societies.

CORRESPONDENCE.

FIGHT BETWEEN A TROUT AND A WATER-SNAKE.

To the Editor of the Popular Science Monthly.

HAVING read in your July number Mr. Buckland's account of a fight between a scorpion and a mouse, I am induced to give you an account of a remarkable conflict between a large water-snake and a trout, witnessed by myself and one of my brother officers in the survey in 1867, on the Purissima, a small trout-stream which empties into the ocean about twenty-four miles south of San Francisco. We had been fishing on the stream, and came to a high bank which overlooked a transparent pool of water about ten feet in diameter and four feet in depth. This pool was fringed with willows, and had on one side a small gravel-bank. The trout at first sight was lying in mid-water, heading up-stream. It was, as afterward ascertained, fully nine inches in length, a very desirable prize for an angler. While studying how to cast our flies to secure him, a novel fisherman appeared, and so quick were his actions that we suspended our own to witness them. This new enemy of the trout was a large water-snake of the common variety, striped black and yellow. He swam up the pool on the surface until over the trout, when he made a dive, and by a dexterous movement seized the trout in such a fashion that the jaws of the snake closed its mouth. The fight then commenced. The trout had the use of its tail and fins, and could drag the snake from the surface; when near the bottom, however, the snake made use of its tail by winding it around every stone or root that it could reach. After securing this tail-hold it could drag the trout toward the bank, but, on letting go, the trout would have a new advantage. This battle was continued for full twenty minutes, when the snake managed to get its tail out of the water and clasped around the root of one of the willows mentioned as overhanging the pool. The battle was then up, for the snake gradually put coil after coil around the root, with each one dragging the fish toward the land. When half its body was coiled it unloosed the first hold and stretched the end of its tail out in every direction, and, finding another root, made fast, and now using both dragged the trout out on the gravel-bank. It now had it under control, and, uncoiling, the snake dragged the fish fully ten feet up on the bank, and I suppose would have gorged him. We killed the snake, and replaced the trout in the water, as we thought that he deserved liberty. He was apparently unhurt, and in a few moments darted off. That the water-snake of our California brooks will prey upon the young of trout and also smaller and less active fishes, I have noticed, but never have seen an attack on a fish so large or one more hotly contested. Yours respectfully,

A. W. CHASE,
Assistant U. S. Coast Survey.

EDITOR'S TABLE.

THE NEW YORK AQUARIUM.

THE devotees of rational amusement, the lovers of natural history, and the friends of scientific education, in this city, are to be congratulated on the establishment of the aquarium which was recently completed and opened to visitors. Undoubtedly the devotees of rational amusement are not so numerous as they might be, but they will increase in numbers as increasing facilities are afforded for combining agreeable recreation with instructive observation in the acquisition of pleasant knowledge without much trouble. As a means of increasing the general taste in natural history, and affording students the opportunity of familiarizing

themselves with forms of life hitherto inaccessible and known chiefly in books, the aquarium is invaluable, and will be a great help in promoting the work of science. The museum shows us dead specimens, stuffed, dried, and variously preserved, and is of course not without interest. But the aquarium opens to us the living, moving curiosities and wonders that are nowhere else to be seen. What the menagerie is to the creatures of the forest, the desert, and the prairie, the aquarium is to the tenants of the lake, the river, and the ocean. But, while land-animals have long been captured and collected for inspection, the aquarium is a new and recent affair, involving great difficulties in its successful management. These difficulties can only be overcome at large expense, by persevering experience, and through special and thorough knowledge of the conditions of life of an immense variety of aquatic creatures. The opportunity such an establishment opens to the scientific observer, investigator, and experimenter, should be highly prized, and we have no doubt it will be well appreciated by this class of students.

In an educational point of view, or as a means of popular instruction, a well-stocked aquarium cannot fail to be of the highest value. Natural history is a growing subject in our schools, but is so generally pursued merely from text-books which give no real knowledge, that a great available museum of living objects is precisely what is wanted to give reality and efficiency to this branch of study. The New York Aquarium should be brought into very close relations with the common-school system of the city. We are glad to observe that this element of its usefulness has not been overlooked in the plan and management of the enterprise. Provisions for study, instruction, and systematic observation have been incorporated with it, and this feature has been held so important as to be placed in special charge of a cultivated naturalist. Mr. W. S. Ward, who has been abroad this season and visited the chief aquariums of Europe, with a view of acquiring information that will be valuable to the scientific management, will devote himself to the educational service of the institution.

It is a noteworthy fact that we are indebted for the New York Aquarium entirely to private enterprise. There was talk that the city would establish something of the kind in the Central Park; but it came to nothing, and, after the municipal fizzle over the fossil restorations undertaken by Mr. Waterhouse Hawkins, we may conclude that it was perhaps best that the city did not undertake this work. But what it was unable or disinclined to do has been projected and carried out by the persevering enterprise of Mr. W. C. Coup, who has devoted his energy to its organization, and risked his money upon his chance of success. The aquarium is an honor to this metropolis and promises a large benefit to the public, and it should be liberally patronized and well sustained. We have no doubt it will meet from all classes with the encouragement it certainly deserves.

A CASE IN MENTAL PHYSIOLOGY.

An account comes to us of an enterprising Englishwoman who was equal to the following exploits in sharp practice: "By a series of the most extraordinary misrepresentations and cleverly carried out impostures, she raised large sums of money on no security whatever, and spent them as recklessly; imposed on jewelers so that they trusted her with goods worth many hundreds of pounds; furnished grand houses entirely at the expense of trusting upholsterers; introduced herself by sheer impudence to one great nobleman after another, and then introduced her dupes, who, on the faith of those distinguished

social connections, at once disgorged more money. To one person she was a great literary character; to another, of royal descent; to another she had immense expectations; to another, she was a stern religionist."

This woman must have been as smart as she was unscrupulous. Her capacity of imposture was as marked as the deficiency of moral sense; she was as shrewd and long-headed as she was knavish. The art of her conduct, the consummate calculation, and the skillful adaptation of means to ends in dealing with others, implicate the whole intellectual sphere of action which was at the same time exempt from the control of conscience. Yet the force of moral considerations was implied throughout as she had to deal with people who were influenced by them, and to give good reasons for her various claims and representations. It was a sufficiently obvious case of cool criminal depravity, and most people would have little difficulty in deciding what was to be done about it. But current theories of conduct stop with mental *effects*. Mind being regarded as having a sphere of its own, and the mental world being held as an independent world, where all that goes on is purely psychical, there is no interest or requirement to look beyond the open manifestations of mind to their causes in another sphere. If we should say that this woman had something more than a mind, something more than an immaterial responsible soul, that we must look deeper than the mental manifestations displayed in conduct, that she had a brain made up of cells, fibres, tissues, and circulating blood, subject to the laws of nutrition, waste, and repair, debility, degeneration, and disease, and that all these things must be taken into account as controlling conditions of mental effects, we should be met immediately by the cry of *materialism!* And if we should furthermore say that these three or four pounds of nervous matter must come into consideration before society can proceed to decide upon such a case, a cry of denunciation would be raised against a destructive materialism that threatens to subvert the order of society.

Nevertheless, the question of mind in this case was an organic problem of the brain, as the further facts will show. This woman had lived a quiet but honest and uneventful life up to the time that she suddenly struck out into her sensational career. A year of lying, cheating, and scheming practices ended in the development of marked insanity and brain-disease, when she was taken to the Royal Edinburgh Asylum for the Insane, where she soon died. The victims of her cunning and mendacity were simply the dupes of a lunatic, and the question of her character and accountability resolves itself into a problem of brain-derangement, of morbid material conditions, and is therefore a question of practical materialism which the physician cannot escape.

EVOLUTION AND THE COPERNICAN THEORY.

It is significant that nearly all the divines who have spoken, in reply to Prof. Huxley, commit themselves to some form of the doctrine of Evolution. While, however, they admit that there is *some* truth in it, there is a common protest against the idea that it contains *much* truth—not by any means so much as is claimed by Prof. Huxley. He said that the evidence for it is demonstrative, and that it is as well based in its proofs as the Copernican theory of astronomy. This is thought to be quite absurd. It is said that Huxley may know a great deal about animals and fossils, but that obviously he knows very little about logic. His facts being admitted, a great deal of effort has been expended to show that he does not understand how to reason from them.

The Rev. Dr. William M. Taylor, in a letter to the *Tribune*, takes up Prof. Huxley on this ground, and is quite shocked at his logical incapacity. The following is a sample passage from his communication, and a very fair example, besides, of the sort of comment which his lectures have elicited:

"Indeed, to affirm, as he did, that evolution stands exactly on the same basis as the Copernican theory of the motions of the heavenly bodies, is an assertion so astounding that we can only 'stand by and admire' the marvelous effrontery with which it was made. That theory rests on facts, presently occurring before our eyes, and treated in the manner of mathematical precision. It is not an inference made by somebody from a record of facts, existing in far-off and prehistoric, possibly also prehuman ages. It is verified every day by occurrences which happen according to its laws. But where do we see evolution going on to-day? If evolution rests upon a basis as sure as astronomy, why do we not see one species passing into another now, even as we see the motions of the planets through the heavens? . . . We know that astronomy is true, because we are verifying its conclusions every day of our lives on land and on sea. We set our clocks according to its conclusions, and navigate our ships in accordance with its predictions, but where have we anything approaching even infinitesimally to this, with evolution?"

The author of this passage is said to be a man of eminence and ability. That may be, but he certainly has not won his distinction either in the fields of logic, astronomy, or biology. When a man undertakes to state the evidence of a theory, and gives us proofs that equally sustain an opposite theory, we naturally conclude that he does not know what he is talking about. This is very much Dr. Taylor's predicament. In trying to contrast the evidence for evolution with the demonstrative proofs of the Copernican theory, he cites facts that are not only as good, but far better, to prove the truth of its antagonist, the Ptolemaic theory.

Dr. Taylor talks as if the Copernican theory is something that anybody can see by looking up into the sky, but the case is far from being so simple. The Copernican theory of the planetary motions assumes that they take place around the sun as their centre; the Ptolemaic theory taught that the earth is the stationary centre of the system, and that the sun, moon, and planets, revolve around it. We must not forget that the Ptolemaic theory was the fundamental conception of astronomy, and guided its scientific development for two thousand years. It was based on extensive, prolonged, and accurate observations; was elucidated and confirmed by mathematics—geometry, and trigonometry; and was verified by confirming the power of astronomic prevision. The planetary motions were traced and resolved on this theory with great skill and correctness, elaborate tables being constructed which represented their irregularities and inequalities, so that their future positions could be foretold, and conjunctions, oppositions, and eclipses, predicted. It embodied a great amount of exact knowledge, and was capable of taking in and preserving all the new results of the labors of a long series of Greek, Latin, Arabian, and modern European astronomers. Dr. Whewell says of it: "In this sense, therefore, the Hipparchian theory was a real and indestructible truth, which was not rejected, and replaced by different truths, but was adopted and incorporated into every succeeding astronomical theory, and which can never cease to be one of the most important and fundamental parts of our astronomical knowledge."

Copernicus, then, did not abolish but rather revised the old astronomy. He accepted the whole system of eccentrics and epicycles, and, so far as planetary motions are concerned, he simply recentred the solar system. He showed that the evidence in favor of that view preponderated, and his theory was a victory of refined, remote, and indirect investigation.

Dr. Taylor tells us that the Copernican theory "rests on facts presently occurring before our eyes." So does the Ptolemaic theory; and not only that, but, if the test is what occurs before our eyes, then the Ptolemaic theory is a thousand times stronger than the Copernican. If the Copernican theory is so obvious, if it "rests on facts presently occurring before our eyes," why did the astronomers of twenty centuries fail to discern it? Why could not the divines of Copernicus's time see it when it was pointed out to them? And why could not Lord Bacon admit it a hundred years after Copernicus? Dr. Taylor says, "It is verified every day by occurrences that happen according to its laws." So was its opposite, the Ptolemaic theory. Our reverend logician says, furthermore: "We know that astronomy is true, because we are verifying its conclusions every day of our lives, on land and on sea. We set our clocks according to its conclusions, and navigate our ships in accordance with its predictions." And all this they did with the astronomy that preceded Copernicus. Yet the author of this rubbish airs his logical pretensions, and talks about the "effrontery" of Prof. Huxley. Where is his shame?

The Copernican theory is held as demonstrably true, but it is not because everybody can see the demonstration. There was demonstrated truth in the opposite theory, though the proof was not so complete. And in regard to this matter of demonstration, of which so much is said, we have to remember that evidence is a thing of degrees. There may be evidence for a proposition which is so small that we hardly regard its truth as possible—we do not believe it. There is a grade of proof that amounts to probability, but leaves us in uncertainty. There are higher degrees of proof that confer assured belief, and leave little room for doubt. There is, again, evidence so perfect and decisive as to give certainty of conviction, and this we call demonstration. And evidence may have a yet higher shade of intensity, as where we cannot even conceive the opposite of a proposition to be true, and this may be characterized by the frequent expression, "absolute demonstration." The best examples of demonstration are furnished by mathematics in consequence of the fewness and simplicity of mathematical ideas, but demonstration by no means necessarily involves mathematics. There is plenty of demonstrated truth that is not mathematical. The anatomist demonstrates his science by observation, and the chemist by experiment. Fossils found in the rocks demonstrate that life existed upon the globe before the rocks were formed; and the vestiges of art found in Western mounds demonstrate that a race of men superior to the savages formerly lived upon this continent. A theory is said to be demonstrated when it brings all the known facts into agreement, explains them, excludes all other interpretations, and is consistent with itself and all that is understood of the ways of Nature. Most theories of the operations of Nature have about them traces of the imperfection that belongs to all things human, difficulties that are still unresolved, while yet the evidence for them may be so overwhelming as to be held demonstrative.

How is it, now, with the proof of the theory of Evolution, which assumes that the immense diversity of living forms now scattered over the earth has arisen through a long process of gradual unfolding and derivation, within the order of Nature, and by the operation of natural laws? It involves and is built upon a series of demonstrated truths. It is a fact accordant with all observation, and to which there never has been known a solitary exception, that the succession of generations of living things upon earth is by reproduction and genetic connection in the regular order of Na-

ture. The stream of generations flows on by this process, which is as much a part of the settled, continuous economy of the world as the steady action of gravity or heat. It is demonstrated that living forms are liable to variations which accumulate through inheritance; that the ratio of multiplication in the living world is out of all proportion to the means of subsistence, so that only comparatively few germs mature, while myriads are destroyed; that, in the struggles of life, the fittest to the conditions survive, and those least adapted perish. It is a demonstrated fact that life has existed on the globe during periods of time so vast as to be incalculable; that there has been an order in its succession by which the lowest appeared first, and the highest have come last, while the intermediate forms disclose a rising gradation. It is a demonstrated truth of Nature that matter is indestructible, and that therefore all the material changes and transformations of the world consist in using over and over the same stock of materials, new forms being perpetually derived from old ones; and it is a fact now also held to be established, that force obeys the same laws. All these great truths harmonize with each other; they agree with all we know of the constitution of Nature; and they demonstrate evolution as a fact, and go far toward opening to us the secondary question of its method.

The reverend writer, whom we have quoted, asks, "If evolution rests on a basis as sure as astronomy, why do we not see one species passing into another now, even as we see the motions of the planets through the heavens?" To this foolish question, which has nevertheless been asked a dozen times by clerical critics of Huxley, the obvious answer is, that what requires a very long time to produce cannot be seen in a very short time. Has the writer ever seen the production of a geological formation? That he has not seen the evidences that would have prevented him from asking such a question is probably because he is not a student of Nature, and has not looked for them.

There has been much complaint that Prof. Huxley undertook to put the demonstrative evidence of evolution on so narrow a basis as the establishment of the genealogy of the horse, but this rather enhances than detracts from his merit as a scientific thinker. It has been well remarked that "the genius of the discoverer appears in his perceiving how small a number of facts, rightly considered, are sufficient to form a foundation for a theory." Kepler had to fix but a few points in the path of Mars, to demonstrate the ellipticity of his orbit, and to subvert the theory of circular planetary motions, by which the way was paved to the Newtonian astronomy. Prof. Huxley could have accumulated a far more striking display of the proofs of evolution for a popular audience, but he preferred to rest the question on evidence that was none the less decisive because it was restricted. If the horse has been derived from preceding forms in the way he pointed out, then that is the method of Nature—unless we deny the unity of its order.

And here is the vital point between Prof. Huxley and his antagonists. It is a question of the validity of the conception of the order and uniformity of Nature. Prof. Huxley holds to it as a first principle, a truth demonstrated by all science, and just as fixed in biology as in astronomy. His antagonists hold that the inflexible order of Nature may be asserted perhaps in astronomy, but they deny it in biology. They here invoke supernatural intervention. Obviously there are but two hypotheses upon the subject, that of the genetic derivation of existing species, through the operation of natural law, and that of creation by miraculous interference with the course of Nature. If we assume the orderly course of Nature, development

is inevitable; it is evolution or nothing. If the order of Nature is put aside and special creation appealed to, we have a right to ask on what evidence? It was long maintained that the universe was made in a week, by a quick succession of divine fiats. This view is now abandoned, and it is maintained, *as a new theory*, that the millions of species which science has proved to have appeared all along the course of geological time were also the products of miraculous agency. But, as logic has been appealed to, we again press the question, on what evidence? There is no evidence. There is not a scintilla of proof that can have a feather's weight with any scientific mind. We are told that each link in the chain of ancestry of Prof. Huxley's horse was a special creation. But who tells us this, and what do they know about it? Genetic derivation is in the field as a real and undeniable cause; but what possible ground is offered for the alternative supposition? Has anybody ever seen a special creation? Do those who believe in it represent to themselves any possibility of how it could have occurred? Milton attempted to form an image of the way the thing was done, and says that the animals burst up full-formed and perfect like plants out of the ground—"the grassy clods now calved." But clods can only calve miraculously. Nature does not bring them into the world now by this method, and science certainly can know nothing of it. So far from being possible, so far from being probable, so far from being proved, this hypothesis of the origin of animal forms is simply unthinkable; it is a violation not only of the order of Nature, but of the very conditions of thought. From this point of view, therefore, the theory of evolution differs from the Copernican theory by having no alternative possibility. The Copernican theory was but the revision and modification of a preceding theory which had evidence in its favor, and could be rationally held by scientific minds; the evolution theory has a force of demonstration derived from the fact that the only alternative view cannot for a moment be entertained by any mind that recognizes the logical force of scientific evidence; in this respect, therefore, the evidence for evolution is even stronger than that for the Copernican theory.

LITERARY NOTICES.

The Theory of Sound in its Relation to Music. By Pietro Blaserna, of the Royal University of Rome. With numerous Illustrations. Pp. 187. Price, $1.50. International Scientific Series, No. XXII.

Nothing could be more appropriate than that the first Italian contribution to the "International Scientific Series" should take up one of the most interesting relations of science to art. Italy has been long preeminent as the land of artistic genius, although her distinction has been chiefly won by cultivating the arts that appeal to the eye—painting, sculpture, and architecture. Germany leads in the modern development of musical art, and her great physicist, Helmholtz, stands first as the elucidator of the laws of sound applied to musical science. But the great work of Helmholtz is a sealed book to the people. Prof. Blaserna has been first to take the brilliant results of recent acoustical progress and apply them to musical art and theory in so clear and familiar a manner that common readers will follow him with ease and pleasure.

The work is addressed both to scientific students and to musicians, but it is properly a contribution to the science of music. It does not at all cover the ground of Prof. Tyndall's volume on "Sound," which is strictly a text-book of acoustics, but, starting with so much of acoustical principles as is necessary for his purpose, Prof. Blaserna devotes the work to those scientific elucidations of musical art and practice which will have the greatest interest to those concerned in musical study. We cannot better give account of the volume than by quoting freely from the admira-

ble review of it that has just appeared in the London *Lancet.* The writer says: "This work is an attempt to popularize the theory of music, and so to combine the theoretical with the practical study of this art that instrumentalists may obtain some knowledge of those fundamental laws of sound on which music is based. With this object in view Prof. Blaserna commences his treatise by explaining the laws of vibrations of strings and pipes, and shows how such vibrations may be measured; he then explains the theory of music in reference to the consonant and dissonant intervals, pointing out how the various ratios in the octave have been introduced, together with the nature of the perfect major and minor chords, the inversion of which, he observes, constituted the principal resource of Palestrina and of the composers of his school. This leads him to speak of dissonances, and of the nature of the musical scales. An exceedingly interesting *résumé* is then given of the history of music from the earliest period to the present day. In the music of all nations, Prof. Blaserna remarks, two unfailing characters are found —rhythmic movement and procedure by determinate intervals. The former appertains to many of the actions of man, but the second belongs exclusively to music. The instrument of Orpheus, however powerful its effects may have been in rendering inanimate objects 'sequacious of the lyre,' was but a poor instrument, consisting only of the following four notes: C, F, G, and the octave C. It is remarkable that this scale contains the most important musical intervals of declamation, the voice rising a fourth in making an interrogation, another a fifth higher in emphasizing a word, while in ending a story it falls a fifth. In speaking of Greek music he explains the difference between the Pythagorean and the modern scale. The ancient Scotch and Chinese scale, in which an enormous number of popular songs are written, consists of a succession of fifths, B*f*, F, C, G, D.

"The inventor of the modern system of musical notation was Guido d'Arezzo, and by him and Josquino and Orlando Tasso polyphonic music underwent great development. Then came the Reformation, and church music was greatly simplified to enable the whole congregation to join in it. An elaborate discussion of the characters of the major and minor scales succeeds, with an account of the effects of transposition. The temperate scale in common use is then explained, and its imperfections are declared to be so manifest that the author expresses a hope it will eventually be abolished. It is, in fact, only maintained by the piano-forte, which is essentially the instrument of the temperate scale, and the defects of which have greatly tended to obscure pure melody. The quality or timbre of musical sounds, both vocal and instrumental, is then referred to, and the methods of investigating the vibrations are given, as well as the laws of harmonics and chords. Finally, Italian and German music are compared. The influence of Paris on music, though the French have never been creators, is defined as insisting on the creation of a type of music which should contain the good points of the German and Italian schools without their exaggeration. It has maintained the Italian melody and song, but has also adopted the grand choral and orchestral movements of Germany."

The Races of Man and their Geographical Distribution. By Oscar Peschel. Translated from the revised German edition. New York: D. Appleton & Co. Pp. 528. Price, $2.25.

The students of ethnology are to be congratulated on the appearance in English of this admirable manual of ethnological and ethnographical science, which has for some years and in its successive editions been a standard in Germany. While the work is full and systematic, it is at the same time compact and convenient for reading, being a happy medium between the bulky and formidable treatise, and the deficient and unsatisfying compend. Dr. Peschel's work has the great merit of being up to date in the presentation of an extensive and rapidly-developing branch of science, and of dealing fully with those recent and highly-important questions concerning the science of man which have come forward into such prominence in our own generation. The book is exactly what readers of general cultivation require to inform themselves upon a subject of great moment, and which is occupying the close attention of thinkers

in all nations; and it will also be of a special value to the scientific students of ethnology, not only for the breadth and care of its discussions, and the immense amount of information condensed in its text, but also for the copious wealth of its references to the literature and authorities of the subject.

No just idea of its broad range of interesting topics pertaining to the nature, characters, habits, and diversities of man, can be conveyed in a brief notice of the work. But, as its materials are derived from the most instructive portions of history, from the descriptions of races furnished by travelers, from wide geographical observation, and from the various sciences which illustrate the constitution of man and his intercourse with surrounding Nature, the facts brought forward have a very wide diversity of interest, so that we cannot dip into the volume anywhere without becoming quickly absorbed in the question under consideration.

The book is divided into two parts. In the introduction to the first part the author devotes himself to the question of man's place in creation, of the unity or plurality of the human race, of the place of its origin and the problem of its antiquity; then follows a series of disquisitions on the physical characters and the linguistic characters of man, and the industrial, social, and religious phases of his development. The second part is descriptive of the races of mankind, which are taken up in their leading divisions, and in their geographical distribution, and considered with as much detail as the limits of the work will allow. The book, of course, has nothing like the comprehensiveness or strictness of method and classification that characterizes Mr. Spencer's great work, "Descriptive Sociology;" nor has it the depth and completeness of analysis of social phenomena that mark the "Principles of Sociology" by the same author; but, as a *résumé* of the subject in a single handy volume, we have probably nothing so good in the language.

Report of the Geological Survey of Ohio. Published by authority of the Legislature of Ohio. 4 vols. Columbus: Nevins & Myers, State Printers.

The first geological information obtained concerning the State of Ohio was derived from a report made by a committee which took its observations in the summer of 1836. Geology was then a science in a preliminary stage of development, and the application of the existing knowledge was impeded by ignorance of the general outlines of the country. Paleontology was in much greater obscurity, and it is natural that the report of that period should seem imperfect at the present time.

In March, 1869, the Legislature passed a bill authorizing a complete survey of the State by a committee of competent men. In addition to a minute geological investigation, they were to make a careful chemical analysis, including a classification of the various soils, and the best means for promoting their utility; and were to take observations to determine the local causes producing variations of climate, etc.

The officers appointed were Prof. J. S. Newberry, chief geologist; Edward Orton and E. B. Andrews, assistant geologists; T. G. Wormley, chemist; F. B. Meek, paleontologist, besides a number of local assistants. They entered upon their work June 1, 1869, and finished it June 1, 1874, at a cost of $256,000, including the publication of four volumes of reports. For rapidity of action, thoroughness of results, and moderation in the expense, this survey contrasts most favorably with those made in other States. Thus far there have been published two volumes on geology and two on paleontology, with maps of some of the counties. In the volumes on paleontology there are a large number of plates and illustrations, which are admirable specimens of careful work and beauty. Ohio is rich in fossil remains, having contributed largely to the cabinets of other States, and this is the first occasion on which they have been presented to the public. The plan of the corps was to publish six volumes, two on geology, two on paleontology, one on economic geology, and one on zoölogy, botany, and agriculture. The last two volumes have not yet been published, though the work of composition is far advanced.

Surveys had been made previous to this one in many of the other States, which presented discrepancies that had given rise to much bitter discussion. It was, therefore, of importance that Ohio should be thoroughly explored, as it formed the key-

stone in the arch reaching from the Alleghanies to the Mississippi, and offered the probable means of solving the perplexing difficulties.

According to Prof. Newberry, "the topographical features may be described as those of a plain slightly raised along a line traversing it from northeast to southwest, and worn in the lapse of time by the draining streams into broad valleys, which impart a pleasing variety to the surface, afford free and healthful drainage, and yet leave unimpaired all the productiveness of its original monotony; in fact, exhibiting perhaps the most perfect adaptation to the wants of man which any surface affected by such climatic influences can present." The climate is one of extremes. The soil over much more than half the State is of foreign origin, being transported by Drift agencies frequently from a great distance. The physical substructure is not simple like the surface, but is diversified in different places, both as to the number, character, and thickness of the strata, and the position which they occupy relative to each other and to the horizon. The coal-measures underlie the surface of the southeastern third of the State, there being an aggregate of about 12,000 square miles over which the coal is unequally distributed. All the coals are classed as bituminous, and are divided into dry or furnace coals, coking-coals, and cannel-coals, by far the greater portion being of the coking variety. It is proposed to discuss the distribution, qualities, and uses of the coals in the volume on economic geology.

Manual of the Vertebrates of the Northern United States, including the District east of the Mississippi River and north of North Carolina and Tennessee, exclusive of Marine Species. By David Starr Jordan, M. S., M. D., Professor of Natural History in N. W. C. University, and in Indiana State Medical College. Chicago: Jansen, McClurg & Co. 12mo, pp. 342. Price, $2.00.

The object of this work is to facilitate the classification of vertebrate animals by means of artificial keys, such as have been used in the study of botany. It has been prepared for the use of collectors and students who are not specialists, and has been compressed within the narrowest limits in order to render it as cheap a handbook as possible. There are descriptions of 817 species, representing 116 families. It is the only work containing arranged descriptions of the reptiles and fresh-water fishes of this country.

The Centennial Situation of Woman. A Commencement Address at Mount Holyoke Seminary, by Hon. Alexander Bullock. Charles Hamilton, Worcester, Massachusetts. Pp. 45.

Governor Bullock made an eloquent speech to the South Hadley ladies, but whether he was quite equal to the occasion may be a question depending upon the view taken of the duties of such an opportunity. Some may think that, in reviewing a hundred years of progress in public or social affairs, it is most suitable to take note of what has been gained; to dwell upon the triumphs, the causes of congratulation, and give indulgence to the more complacent feelings. Others may regard it as the most fitting time to be on our guard against this ever-besetting tendency, the time to survey closely and critically the position that has been reached, to sift current claims, to look sharply after mistakes, and utilize an impressive occasion to forecast the best course of action for the future. Governor Bullock took the most agreeable alternative, and discoursed pleasantly, and with commendable gallantry, of what woman has done to improve her condition in various ways, and what civilization has accomplished for her in furtherance of the same end. He points out the progress that woman has made toward the independence of self-dependence through the opening to her of modern industries; sketches the changes that have taken place in the recognition of her civil rights; and dwells upon the great advance that has been made in the work of female elevation, and in opening to woman a wide opportunity in the vocation of teaching. He touches lightly the vexed question of the intellectual equality of the sexes, saying it has been settled that there is no question at all about it, and deftly quotes a woman—Mrs. Jameson—as expressing the opinion that "the intellect of woman bears the same relation to that of man as her physical organization; it is inferior in power and different in kind. In men the intellectual facul-

ties exist more self-poised and self-directed, more independent of the rest of the character, than we find them in women, with whom talent, however predominant, is in much greater degree modified by the sympathies and by moral causes." The Governor evades the question of suffrage for woman, but is adverse to her participation in public affairs. He cites Franklin as saying that "women should not meddle with party politics, except in the endeavor to reconcile their husbands, brothers, and friends, who happen to be of contrary sides;" and he reminds the listening ladies of the pleasantry of Addison, who remarked: "There is nothing so bad for the face as party zeal. It gives an ill-natured cast to the eye, and a disagreeable sourness to the look; besides that, it makes the lines too strong, and flushes them more than brandy."

The Kinematics of Machinery: Outlines of a Theory of Machines. By F. Reuleaux, Member of the Royal Trade Commission. Translated and edited by Alexander B. W. Kennedy, C. E., Professor of Civil and Mechanical Engineering in University College, London. With numerous Illustrations. London: Macmillan & Co. Pp. 622. Price, $7.50.

The number of inventions during recent years has been so great that it is almost impossible to classify the different machines, or to observe any regular system connecting them. This country possesses no systematized instruction or extended literature in regard to machinery, and, although it has been peculiarly rich in inventions, the results would undoubtedly have been more satisfactory if they had been effected according to an arranged method. In this book the theoretical part of machinery alone is treated. The author attempts to give a thorough understanding of its essential nature, by which problems previously unsolvable may be made clear, and by which greater practical results may be reached. In his own words, his purpose is "to determine the conditions which are common to all machines in order to decide what it is, among its great variety of forms, that essentially constitutes a machine. . . . The book is intended, not so much to add to the positive knowledge of the mechanician, as to increase his understanding of what he already knows, so that it may become more 'thoroughly his own property.'" In the old books, each machine was taken up as a whole, and treated by itself. But, as it was discovered that similar parts occur in different machines, the method continually grew more simple. Prof. Reuleaux endeavors to place the science in a position in which it may become deductive, and in which the study may depend upon a few fundamental truths. With him, motion is but a change of position, and the changes are conditioned simply by the geometric form of the moving bodies.

In this volume fluids also take their place as forming a part of machinery, and instances are given in what forms engineers may use them to the greatest advantage. The work, which was written in German, has been published in Italian, and is now being translated into French.

The Ethics of Benedict de Spinoza. From the Latin, with an Introductory Sketch of his Life and Writings. New York: Van Nostrand. Pp. 375. Price, $3.00.

This volume has a peculiar interest in being the first American translation of the "Ethics" offered to the public. As it has been preceded by only one English translation, the book will supply a want in this country, and meet the demand of those who desire to obtain a clear idea of Spinoza's philosophy. The object which Spinoza had, in developing his system, was to discover certain rules by which he might govern his own actions. To accomplish this, he begins with a number of definitions and axioms from which his principles are evolved in regular geometrical order. The work is divided into five parts. In the first part is set forth his conception of God—an absolutely Infinite Being or substance, without beginning or end, and *causa sui*. Nothing can be thought of outside of God, and everything which exists does so through God. In the second part are treated the origin and nature of the human mind and soul. In the third, fourth, and fifth parts, an investigation is made of the passions, their causes and effects, their force and the manner in which they should be governed. The end arrived at is, that the pleasures of

sense and intellect should balance each other, and in this manner the greatest happiness be secured. Thus, by a different process of reasoning, he arrives at a result similar to that reached by the Christian religion. Whatever may be thought of this as a religious or logical system, yet, taken as a whole, it is a work of the purest morality. The "Ethics" is the product of the reasoning powers and not of the imagination. Its general style and literary character are at great variance with the smooth disquisitions of modern times, but, if these mechanical effects are overlooked, the thoughtful reader will find the truths as new and striking as when they were first written.

In the preface is given an outline of the author's life, with the effect produced by his writings. The translation has been made with care and skill, and differs from the English translation in being somewhat more concise, while it is at the same time equally clear.

Comparative Zoölogy, Structural and Systematic. For Use in Schools and Colleges. By James Orton, A. M., Professor of Natural History in Vassar College; Corresponding Member of the Academy of Natural Sciences, Philadelphia, and of the Lyceum of Natural History, New York; author of "The Andes and the Amazon," etc. New York: Harper & Brothers, 1876. Price, $3.00.

This volume, as we are informed by the author in the preface, is "designed solely as a manual for instruction, and to present clearly, and in a somewhat new form, the established facts and principles of zoölogy." It is claimed for it "that the selection and arrangement of essential principles and typical illustrations are from the standpoint of the teacher. . . . and that a distinctive character of the work consists in treating of the whole animal kingdom as a unit, and in the comparative study of the development and variation of organs and functions from the simplest to the most complex state."

The work is divided into two parts, the first of which treats of structure, the second of systematic zoölogy, the plan of the author being to withhold from students the study of the classification of animals until "they have mastered those structural affinities upon which true classification is founded."

In both divisions of the work the synthetic method is employed, as being the most natural one, a study of simple structures and forms being first introduced.

The plan of the work is comprehensive, and claims to represent the latest phases of the science of zoölogy. Comparative zoölogy is defined as "the comparison of the anatomy and physiology of all animals existing and extinct, to discover the fundamental likeness underneath the superficial differences, and to trace the adaptation of organs to the habits and spheres of life."

The style is usually clear and attractive, and the book may be read with interest and profit by others than teachers and students. But we notice some passages which are obscure from brevity, others from inadvertence; and there are several inaccuracies, all of which it will be found more easy to correct in a second edition than it was to avoid in the first.

One feature of the work will neither be overlooked nor excused by naturalists. Of about 350 illustrations, a very large number, probably 300, are old, and have done service several times before. If some of these cuts are excellent and appropriate, others could have been omitted without detriment, while new ones illustrating American types are needed.

The value of the work is enhanced by copious notes, 220 in number, at the close of the volume.

What Young People should know. The Reproductive Function in Man and the Lower Animals. By Burt G. Wilder. With Twenty-six Illustrations. Boston: Estes & Lauriat. Pp. 212. Price, $1.50.

Prof. Wilder, being convinced that there are greater evils caused by ignorance of the legitimate and illegitimate uses of the reproductive organs than by the perversion of any other human propensity, has written this book to dispel the ignorance. If there were real knowledge upon such subjects, he thinks there would be no exercise of the imagination in regard to them. Few will agree with him in this idea, however excellent his work may be as a physiological treatise for the young in this special branch.

Practical Botany, Structural and Systematic, etc. By August Koehler, M. D., Professor of Botany in the College of Pharmacy of the City of New York. Copiously illustrated. New York: Henry Holt & Co. 12mo, pp. 400. Price, $3.00.

The author, believing that "the study of botany cannot become truly profitable until a number of plants have been identified by the student, and their images received into his memory," has constructed a book which is an artificial key to "stimulate the unlearned," and act as a labor-saver to those already somewhat acquainted with the science. It departs from the ordinary system of classification, in being arranged according to the old dichotomal method. The natural tendency of this might, perhaps, be to suggest names rather than the association of principles. Those, however, who are desirous of rapid action, and speedy results, will find here a book for their purpose in a neat and convenient form.

Theory of Medical Science: The Doctrine of an Inherent Power in Medicine a Fallacy. The Ultimate Special Properties of Vitality and the Laws of Vital Force constitute the Fundamental Basis of Medical Philosophy and Science. By William R. Dunham, M. D. Boston: James Campbell. Pp. 150. Price, $1.25.

The title-page speaks for itself, and indicates the theory on which this book was written. The work was published with the hope that it might recover the "fundamental principles involved in a correct theory of medical science," assist the profession in the details of practice, and enable the non-professional to distinguish between quackery and rational practice. The author finds fault with the medical profession because it continues to follow the ancient interpretations of the science, but seems unwilling himself to adopt the results of those who are doing most for the furtherance of correct principles in regard to mind and body.

California Notes. By Charles B. Turrill. San Francisco: Bosqui & Co. Price, $1.50.

The "Notes" is a description or guide through different sections of California, in which the author conducts his readers to the places visited by him. Among the subjects represented in the book are, "San Francisco," "Into the Heart of the Foot-Hills," "Calaveras County," "Gold-Mines," "The Yosemite Valley," etc. This volume is the initial number of a series.

Elements of Physical Manipulation. By Edward C. Pickering, Thayer Professor of Physics in the Massachusetts Institute of Technology. Part II., pp. 316. Price, both parts, $4.00.

This second volume, like the first, is designed as a special text-book for the laboratory. The text is made up principally of experiments, giving a description of the instruments to be used, and a plan of what is to be done. Among the subjects discussed are "Electricity," "Meteorology," and "Astronomy." The latter is a new feature in laboratory practice, but there is no reason why it should not be taught practically, as well as chemistry or physics.

PUBLICATIONS RECEIVED.

The Religion of Evolution. By M. J. Savage. Pp. 253. Boston: Lockwood, Brooks & Co. Price, $1.50.

The Symbolical Language of Art and Mythology. By R. P. Knight. Pp. 267. New York: J. W. Bouton. Price, $3.00.

Essays on Mind, Matter, Forces, etc. By Charles E. Townsend. Pp. 404. New York: Somerby.

Chemia Coarctata. By A. H. Kollmyer. Pp. 111. Philadelphia: Lindsay & Blakiston. Price, $2.25.

Matter and Force. By J. K. Macomber. Pp. 100. Ames, Iowa: Agricultural College print.

Ancient Pagan and Modern Christian Symbolism. By Thomas Inman, M. D. Pp. 187. New York: Bouton. Price, $3.00.

Elementary Hand-book of Applied Mechanics. By W. Rossiter. Pp. 150. New York: Putnams. Price, 75 cents.

Elementary Hand-book of Theoretical Mechanics. Pp. 146. Same author and publisher. Price, 75 cents.

Geological Survey of Indiana (1875).

By E. T. Cox. Pp. 600. *Indianapolis Sentinel* print.

Public Libraries in the United States. Part I., pp. 1222; Part II., pp. 89. Washington: Government Printing-Office.

Essays in Literary Criticism. By R. H. Hutton. Pp. 344. Philadelphia: J. H. Coates. Price, $1.50.

Vaccination as a Preventive of Small-pox. By W. C. Chapman, M. D. Pp. 91. Toledo, Ohio: Brown & Faunce.

German and American Brewers' Journal. Semi-monthly. $5.00 per year. Brewers' Publishing Company, 20 Park Place, New York.

On Cephalization. By James D. Dana. Part V., pp. 7. From *American Journal of Science and Arts.*

Report of the Condition of the Academy of Natural Sciences of Philadelphia. By W. S. W. Russhenberger. Pp. 56. Philadelphia: Collins print.

Essential Piety of Modern Science: a Sermon. By J. W. Chadwick. Pp. 31. New York: Somerby.

Surface Drainage of the Metropolitan (Boston) District. By C. W. Folsom, C. E. Pp. 4. From Report of Massachusetts Board of Health.

A List of Orthoptera. By Dr. Cyrus Thomas. Pp. 20. From Proc. D. A. N. S., vol. i.

American Library Journal. Monthly. Pp. 27. $5.00 per year. New York: Leypoldt.

MISCELLANY.

Distribution of Plain, Prairie, and Forest.—In the *American Naturalist* for October, Prof. J. D. Whitney gives a very elaborate critique of the various hypotheses which have been put forth to account for the distribution of plain, prairie, and forest, over the North American Continent. The author has no theory of his own to offer, but he appears to show conclusively that none of the accepted theories can be regarded as satisfactory. One of the theories examined by Prof. Whitney is that which attributes the existence of forest, prairie, or plain, to the distribution of rainfall throughout the year, or from season to season. As stated by the late J. W. Foster, this theory holds that "wherever the moisture is equable and abundant, we have the densely-clothed forest; wherever it is unequally distributed, we have the grassy plain (prairie); and where it is mostly withheld, we have the inhospitable desert." This last proposition Prof. Whitney admits, the other two he pronounces erroneous. He cites the vicinity of Chicago, where Mr. Foster lived, in proof of the incorrectness of that author's views. "Here," says Prof. Whitney, "we have the finest prairie-regions in the world, absolutely destitute of trees, and yet in the full enjoyment of an abundant precipitation, and in the immediate vicinity of an immense sheet of water. For Chicago itself, indeed, the statistics of rainfall are very defective, but, such as they are, they are entirely unfavorable to Mr. Foster's hypothesis. Points in the immediate vicinity of that city, where observations have been taken for a series of years, show an average rainfall of thirty-six to fifty inches, pretty uniformly distributed through the year. An excellent instance, on the other hand, of a dense growth of trees combined with the most unequally-distributed rainfall which is possible, is furnished by the western slope of the Sierra Nevada, in California, whose magnificent forests are well known, as also is the fact that there is no precipitation there at all for six months of the year, nearly the whole of the rainfall being limited to three months. And, lest it may be thought that melting snow keeps the ground moist during the summer, it may be added that the heaviest forest-belt of the Sierra is quite below the line above which snow rests for any considerable time, and that the soil in that belt is usually perfectly dry at the surface, and even dusty, for six months of the year, and often much more."

Electrical Phenomena exhibited by Venus's Fly-Trap.—The electrical phenomena exhibited by *Dionæa muscipula* have been investigated by Dr. Burdon-Sanderson, who finds that normally the whole leaf with the petiole is somewhat negative, but, when excited by a stimulus, an electrical

change takes place throughout, making every part more negative. The greatest change is on the external surface of the leaf, immediately opposite to the three sensitive hairs. There is no relation between the preëxisting currents and the electrical disturbance consequent on stimulation. The period of latent stimulation (i. e., the space of time occupied by the primary action of the stimulus) is about one-sixth of a second. The period during which the disturbance lasts is about one second. As the leaf becomes fatigued, the period of latency increases to one second and three-quarters, and then most likely the next stimulation produces no effect. The change appears to be a function of the protoplasm of the parenchyma of the region out of which the sensitive hairs arise. Certain of the characters of the change are similar to those presented by muscle and nerve. Why the variation should be a negative one, Dr. Sanderson is unable to determine.

New Shells from Colorado.—In the extensive and remarkable display of natural-history objects brought to the Centennial Exhibition by Mrs. M. H. Maxwell, of Boulder, Colorado, was a box of land and fresh-water shells. These have been examined by Mr. Ernest Ingersoll, who made careful studies of the Rocky Mountain mollusks in connection with the United States Geological Survey in 1874, and summarized his results in an article printed in this magazine for May, 1876. Boulder is at the mouth of Boulder Cañon, several miles northeast of Denver, at an altitude of about 5,530 feet above the sea, and on the eastern slope of the main range, where heretofore no shells had been found. The list includes *Zonites arboreus*, *Z. fulvus*, *Patula Cooperi* (living, and very dark and fine), *P. striatella*, *Helix pulchella*, *Cionella subcylindrica*, *Vertigo* ——? (very minute), *Succinea lineata*, *S. Nuttalliana*, *Limnea palustris*, *L. desidiosa*, *L. humilis*, *Physa heterostropha*, *Planorbis bicarinatus*, *P. tumens*, *Helisoma plexata*, *Gyranlus parvus*, *Ancylus* ——?, *Goniabasis livescens*, *G. pulchella*, *Sphærium striatinum*, *Pisidium abditum*, and an anodon hardly identifiable.

The collection is remarkable, as coming from the eastern slope of the range, and embracing some unexpected species from east and west. As usual, the *Physas* are *Protean* in form, and one can make half a dozen "species" out of them, if disposed. Some of them are well-marked "*Inflata*." Both the planorbs are reported for the first time from Colorado. *P. bicarinatus* is a well-known Eastern shell; *P. tumens* has hitherto been supposed to be confined to Northern Mexico and Southern California. The *Helisoma* is a new form, discovered by Mr. Ingersoll in an isolated mountain-lake in the southern part of the State, and Mrs. Maxwell finds it at Boulder in a similar situation. Both the *Melanians* and the *Sphærium* are additions to the fauna of the State, and the *Anodonta* will probably prove to be undescribed. Mrs. Maxwell proposes to search still more carefully when she returns, and further information on the geographical distribution of our mollusks in the mountainous territories may be expected from various other quarters where research has been stimulated by the curious results already brought out. Colorado seems to be a meeting-ground for mollusks from all directions, and is a promising field for the collector and student.

Marey's Experiments on the Action of the Heart.—Experiments made by Marey show that a diminution of excitability and a rise of temperature in the muscular tissue of the heart invariably coincide with the cardiac systole, while the opposite phenomena are manifested during diastole. The same author has recently attempted to ascertain whether any corresponding variations of the cardiac muscle could be made out. The galvanometer, owing to the inertia of its needle, is unsuitable for the observation of sudden changes in the intensity of currents. Hence, in Marey's experiments, Lippmann's electrometer was employed. The heart of a frog was placed on two unpolarizable electrodes, one supporting the apex of the ventricle, while the auricles rested on the other. Two successive negative variations of the current were indicated by the electrometer during each cardiac systole; one of these was sudden, and corresponded with the abrupt contraction of the auricles; the other was more gradual, and coincided with the slower

movement of the ventricle. The phases of electrical variation are thus seen to be similar to those of the work done by the muscle.

College Exploring Expeditions.—We learn from the *Tribune* that the present Senior Class of Princeton College has organized a scientific exploring expedition to the West. An association has been formed to train men in scientific studies, and fit them as far as possible for the work to be done. The plan of the association's work is as follows: A knowledge of geology, as good as can be obtained, is required of each man. Then the work is mapped out into subdivisions of natural history and paleontology, and from these each one selects a specialty for himself. The meetings are held fortnightly. At these, the association generally receives an address from some scientific member of the faculty. After this, scientific papers are read by the members, in alphabetical order, four each evening. A question chosen at the previous meeting is then discussed. The faculty have given a room, have arranged the studies to help the association as much as possible, and given facilities for special and outside work. The association is forming a working collection of fossils and minerals, not intended to be complete, but typical. In the mean time the executive committee are taking steps to secure government aid in the shape of wagons, mules, etc., and to get the most favorable possible terms from the railroad companies. If, as is hoped, the committee is successful in obtaining free passes, the expenses will probably not exceed $100 per man. It is not yet fully determined what portion of the West will be explored—probably, however, the Green River, in Wyoming Territory, and Yellowstone National Park, or else the Wahsatch Mountains, will be selected. The membership is limited to thirty regular and ten alternate members. Vacancies occurring in the regular membership are filled from the alternates, who attend all meetings, and perform regular duties.

Eucalyptus as an Anti-Periodic.—Two instances are cited by Dr. Curnow, of London, of the cure of intermittent fever by the use of tincture of *Eucalyptus globulus.* We give in full the author's account of one of these cases, as sufficiently illustrating the action of the drug: S. S——, aged eighteen, a Norwegian, was admitted to King's College Hospital, May 23, 1876. He had been suffering from intermittent fever for four or five weeks. The attacks were moderately severe and of a well-marked tertian type. An expectant plan of treatment was pursued until June 9th, and during this period the paroxysms recurred on alternate days with the utmost regularity. They began at 10 A. M., reached their acme between 1.30 and 3 P. M., and passed off about 6 P. M. The highest temperatures varied from 104.8° to 105.6°. On June 9th the tincture of the *Eucalyptus globulus* was given in one-drachm doses three times daily. The next day, on which another attack was due, his temperature rose to 100°, and on the 12th to 100.4°; and after this date no further paroxysm occurred during the remainder of his stay in the hospital.

Improvements in Iron-Manufacture.—Dr. Andrews, in his inaugural address at the Glasgow meeting of the British Association, referred to the many improvements recently introduced in iron-manufacture. But there yet remains, he said, ample work to be done. The fuel consumed in the manufacture of iron, as indeed in every furnace in which coal is used, is greatly in excess of what theory indicates, and the clouds of smoke which darken the atmosphere of English manufacturing towns, and even of whole districts of country, are a clear indication of the waste, but only of a small portion of the waste, arising from imperfect combustion. The depressing effect of this atmosphere upon the working-population can scarcely be overrated. At some future day the efforts of science to isolate, by a cheap and available process, the oxygen of the air for industrial purposes, may be rewarded with success. The effect of such a discovery would be to reduce the consumption of fuel to a fraction of its present amount; and, though the carbonic acid would remain, the smoke and carbonic oxide would disappear. In the mean time, Dr. Andrews suggests that in many localities the waste products of the furnace might

be carried to a distance by a few horizontal flues of large dimensions, terminating in lofty chimneys on a hillside or distant plain, as is done at the mercury-mines of Idria and some other places. With a little care in the arrangements, the smoke would be wholly deposited in the horizontal flues, and would be available for agricultural uses.

The Tomato-Plant as a Protection against Insects.—In a peach-orchard planted by M. Siroy, a member of the Valparaiso Society of Horticulture, the trees at first grew well and strongly. But, on commencing to bud, they were invaded by the curculio; and this insect was followed, as frequently happens, by ants. While the trees were thus infested, the idea occurred to M. Siroy that by placing leaves around the trunks and branches he might ward off the rays of the sun, which were very powerful. For this purpose he happened to choose tomato-leaves. On the following day he found the trees entirely free from their enemies, not one remaining, except here and there where a curled leaf prevented the tomato from exercising its influence. These leaves he carefully unrolled, placing upon them fresh ones from the tomato-vine, with the result of banishing the last insect, and enabling the trees to grow with luxuriance. Wishing to carry the experiment still further, he steeped in water some fresh leaves of the tomato, and sprinkled with this infusion other plants, roses and oranges. In two days these were also free from the innumerable insects which covered them.

The Age of Paleolithic Man.—Dr. R. H. Tiddeman contributes to *Nature* for October 5th a paper in which he reaffirms the inter-glacial age of paleolithic man and of the fauna with which he is associated. The position not only of human but of animal remains points clearly to the fact of their existence subsequent to a deposit of glacial drift, but previous to another deposit of similar material. The facts may be taken as part of the evidence which proves the disappearance of a great ice-sheet which covered Scotland, England, and portions of the Continent, and the return of it after a period of temperate climate during which man and animals inhabited the region.

The direct evidences of the inter-glacial age of paleolithic man from the actual infraposition of his bones or implements are stated as follows:

1. Victoria Cave, Settle: *a human fibula* under glacial till, and associated with bones of *Elephas antiquus*, *Rhinoceros leptorhinus*, hyena, hippopotamus, etc.

2. At Wetzikon, Canton Zürich, a piece of lignite containing *basket-work* lying beneath glacial deposits, and associated with *Elephas antiquus* and *Rhinoceros leptorhinus.*

3. Near Brandon, Suffolk, *implements* with bones not yet determined in brick-earth beneath the great chalky bowlder-clay of East Anglia.

Dr. Tiddeman says the "Settle till is undoubtedly of the age of the ice-sheet. The Wetzikon lignite lies upon a glacial till beneath a river-gravel on which are great erratic blocks clearly indicating the presence of a great glacier posterior in date to the organic remains. The Brandon implements are beneath the chalky bowlder-clay."

Inequality of the Ocean-Bed.—In opening the Geographical Section of the British Association at Glasgow, Captain Evans said that it was learned for the first time by the Challenger's results—ably supplemented as they had recently been by the action of the United States Government in the Pacific, and by an admirable series of soundings made in the exploratory German ship-of-war Gazelle—that the unbroken range of ocean in the southern hemisphere was much shallower than the northern seas; that it had no features approaching in character those grand abysmal depths of 27,000 and 23,500 feet found respectively in the North Pacific and North Atlantic Oceans, as the greatest reliable depths recorded did not exceed 17,000 feet. The general surface of the sea-bed presented in general to the eye, when graphically rendered on charts by contour lines of equal soundings, extensive plateaux varied with the gentlest of undulations. There was one great feature common to all oceans, and which may have some significance in the consideration of ocean circulation, and as affecting the genesis and translation of the great tidal wave and other tidal

phenomena, of which they knew so little—namely, that the fringe of the seaboard of the great continents and islands, from the depth of a few hundred feet below the sea-level, was, as a rule, abruptly precipitous to depths of 10,000 and 12,000 feet. This grand escarpment was typically illustrated at the entrance of the British Channel, where the distance between a depth of 600 feet and 12,000 feet was in places only ten miles. Imagination could scarcely realize the stupendous marginal features of this common surface depression.

Purification and Deodorization of Petroleum Products.—Mr. S. E. Johnson, of Ashby-de-la-Zouch, England, has discovered a method of treating petroleum and other mineral oils, by which those useful hydrocarbon liquids are not only purified, but also deodorized; and that in a simple and inexpensive manner. Chloride of lime is first introduced into the cask or other receptacle containing mineral oil or spirit, in the proportion of about three ounces of chloride, more or less, to each gallon of the liquid, according to the degree of its impurity, and thus chlorine-gas is evolved in the oil or spirit. If necessary, the evolution of the gas may be assisted by pouring in hydrochloric acid, agitating the contents of the receptacle so as to bring the whole of the liquid into intimate contact with the chlorine-gas. The oil or spirit is then passed into another inclosed vessel containing slaked lime, which, having an affinity for the chlorine, absorbs the same, leaving the liquid sufficiently deodorized and purified.

Physiological Effects of Coca.—A correspondent of the *Lancet*, a physician, states that the use of the tincture of coca, in a two-ounce dose, corrected the "unruly throbbing" of his heart, which had been wont to interfere with his accuracy of aim in fowling. This writer had previously taken the tincture in doses of one-half ounce and one ounce without perceptible effect; but, having on the third day increased the dose to two ounces, his composure was perfect at the critical moment. "As soon as the dogs pointed," he writes, "I expected the usual inward commotion, with its usual results; but, to my surprise, nothing of the kind happened. 'Eureka!' I said to myself; 'the coca has made me a steady shot.' So in fact it subsequently proved. Judged by the effects described," he continues, "coca would seem to be inhibitory as regards the action of the heart. Whether this result is produced by indirect action through the mental functions upon which the drug is said to act remains to be proved." Another correspondent of the same journal, not a physician, states that while traveling in Bolivia at great altitudes, such as from 13,000 to 14,000 feet above the sea-level, he experienced marked benefit from eating the leaves. Nearly all travelers on the Peruvian and Bolivian Andes use the drug as a remedy for that effect on the brain and lungs, produced by rarefied air, which in South America is called *zorroche*. One use to which it is put by the Indians is that of a "pick-me-up" after a debauch on alcoholic fluids. In Bolivia it is generally eaten with a paste made of wood-ashes and potato. The writer propounds the belief that the leaf loses its virtue in transmission. This is quite possible. It is an undoubted fact that the *Cannabis Indica*, for instance, loses its potency in crossing the sea. It would seem desirable that a certain quantity of the coca-leaves should if possible be packed in an air-tight case. The price of coca at La Paz, where the best is procured, was last year sixteen dollars per packet of twenty-five pounds.

The American Forestry Association.—The American Forestry Association held its first meeting at Philadelphia in September. Addresses were delivered by Dr. Franklin B. Hough, of Lowville, New York, Mr. McAfee, and Mr. Meehan. Dr. Hough gave an account of the efforts made by various European governments to preserve forests and to promote timber-culture, and showed that the Constitution of the United States, and those of most of the States, give the right to interfere for the preservation of our forests. Mr. McAfee reported on the condition of forest-culture in the West, showing how the planting of trees had been going on to an immense extent, and that it was found that the old notions about the slowness of timber-growth had been derived from the hard struggle with Nature that wild timber had

to make. Cultivated trees had grown so much faster than was expected that people had been surprised at the growth, and it was now becoming generally known that wood came into profit much sooner than was thought possible years ago, and forest-culture was much more popular in consequence. In his State at least 80,000 acres of timber had been planted during the past few years, and the work was still going on. He gave figures as to the growth of individual species, chiefly from facts within his own observation. Mr. Meehan, from whose *Gardener's Monthly* we take this account of the meeting, thought that the people, without government interference, can be safely trusted with the care of our forests, and the work of reforestation. Individual effort, encouraged by State laws and agricultural and horticultural societies, would soon replace the decaying forests of our land.

How the Menopoma casts its Skin.—Since reading his "Preliminary Note on the *Menopoma Alleghaniense* of Harlan," before the American Association, Grote has observed in the aquarium of the Buffalo Society of Natural Sciences the process by which the menopoma rids itself of its outer skin. This thin and transparent membrane is first seen to loosen and separate from the entire surface of the body, appearing at this stage like an envelope or glove in which the animal is contained. By a number of wide gapings, during which the mouth is opened to the fullest extent, the skin is parted about the lips, and then commences to fold backward from the head. Convulsive and undulating movements with the body and fore-legs are employed to extract these from the loose skin. The skin then readily falls backward, as the animal crawls forward and out of it, until the hind-legs are reached, when the menopoma turns round upon itself, and, taking the skin in its mouth, pulls it over the legs and tail. The operation reminds one of taking off clothes. The cast-off skin is retained in the mouth and finally swallowed. The operation is quickly performed.

Poisonous Cooking-Utensils.—The danger attending the use of porcelain-lined cooking-vessels was pointed out at a meeting of the British Society of Public Analysts, by Mr. Robert R. Tatlock. He stated that the milk-white porcelain enamel with which cast-iron cooking-vessels are now so commonly coated is in the highest degree objectionable, on account of the easy action on it of acid fruits, common salt, and other substances, by means of which lead and even arsenic are dissolved out in large quantity during the process of cooking. It was shown that it is not so much on account of the presence of large proportions of lead and arsenic that these enamels are dangerous, but because they are so highly basic in their character, and are so readily acted on by feebly-acid solutions. He thought that no enamel should be admitted to use unless it was totally unaffected by boiling with a one-per-cent. solution of citric acid, which was a very moderate test. Further, he gave it as his opinion that either the use of such poisonous ingredients as lead and arsenic in large quantity should be entirely discontinued, or that the composition otherwise should be of such a character as to insure that none of the poisonous substances could be dissolved out under ordinary circumstances.

Agencies that formed the Colorado Cañons.—The great cañon of the Colorado is from 3,000 to 6,000 feet deep, through a distance of 200 miles. All the side-streams reach it through profound cañons, and each stream has done, and is still doing, its own work of erosion. The process by which these results are brought about is considered by Prof. G. R. Gilbert, in the *American Journal of Science and Arts*, under three principal heads: 1. Weathering; 2. Transportation; 3. Corrasion.

By weathering, the writer means the disintegration of rock by the action of temperature—beating of rain and changes of vegetation. The process, however, would be greatly delayed if the loosened material was allowed to remain and cover the surface. Hence transportation becomes a powerful agent in erosion, not only by exposing the disintegrating surfaces, but by mechanical wear in the act of removal.

All rocks are more or less soluble in water, and impurities in the water intensify solvent action. But it usually happens that

rocks disintegrated in this way merely fall to pieces, the hard portion remaining in the shape of sand or pebbles. The transportation of this by streams produces what the author calls *corrasion*. In this way the bed of a stream is widened and deepened, but the work is also facilitated by the ceaseless action of water in dissolving the rocks.

The mechanical wear or erosion by a stream depends largely on its velocity. "A stream of water flowing down its bed expends an amount of energy that may be measured by the quantity of water and the vertical distance through which it descends."

The velocity of a stream would continually increase if none of its energy was consumed in friction, but very much of it is so consumed, and reappears in innumerable forms of movement or subsidiary currents. It is by some of these that the work of transportation and erosion is largely done. But a stream may be overloaded with detritus, and its corrading power correspondingly diminished. "Only with a partial load does a stream wear its bottom." Of the Colorado plateau the author says that the erosion which began with the first lifting of a part above the ocean has progressed continually to the present time. The total uplift has been about 12,000 feet; only 7,000 feet remains, that being the present altitude above the level of the sea. Five thousand feet of the general surface has been removed, and an amount greater by several thousand feet has been corraded by the rivers.

Improved Railway-Signal.—A simple and effective railroad-signal, in use on the Boston, Lowell & Nashua Railroad, is described in the *Scientific American*. A single-cell Calland battery is connected to the two rails at one end of a given section of the line—say, two miles in length—each section being insulated from adjoining sections. At the other end the signal has an electro-magnet similarly connected to the two rails. When the circuit is closed, as is normally the case, the magnet is excited and the signal controlled thereby so as to show that the line is clear. But, when a train runs on the section, then a shorter circuit is made by the wheels and axles, and the current returns to the battery by this course, instead of passing through the signals. The magnet ceases to attract, and the signal by mechanical means is at once turned, to indicate danger. It is obvious that this must occur as long as a single car remains on the track, or when the circuit is broken by a displaced or ruptured rail or any other cause. Hence the device may be applied over an entire line, and will indicate the condition of every section to a train about to enter on the same. It is found to be operative in all weathers.

Powder-Paper.—A substitute for gunpowder has been invented in England, called "powder-paper," viz., paper impregnated with a mixture of potassic chlorate, nitrate, prussiate, and chromate, powdered wood-charcoal, and a little starch. The powder-paper is rolled into the shape of a cartridge of any required length or diameter. The manufacture involves no danger, it is said; no explosion can take place except by way of contact with fire. The powder-paper leaves no greasy residue on the inside of the gun; it also produces less smoke, gives a less violent recoil, and is less impaired by humidity than gunpowder. With equal charges, by weight, of gunpowder and powder-paper, the penetrating power of the latter is $\frac{5}{16}$ greater than that of the former.

October Meteor-Shower.—In a letter to the *Tribune*, dated October 19th, Mr. Daniel Kirkwood states that shooting-stars in unusual abundance were observed by several trustworthy witnesses at Bloomington, Indiana, on the evening of the 18th, from six hours forty-five minutes to nine hours. The meteors appeared to radiate from Auriga, or rather from a point between Taurus and Auriga. Most of the meteors were small, though two of them possessed extraordinary brilliancy. In a small work on comets and meteors, published three years ago, Mr. Kirkwood called attention to the fact that meteoric showers had been observed at the same period of the year in 1436, 1439, 1743, and 1798. Returns of the shower were observed in 1838 and 1841. He recommends that a careful watch be kept in future about the same period—say, from the 16th to the 20th of October.

Do Plants absorb Diatoms?—Prof. John Phin, in the *American Journal of Microscopy*, criticises the results of Wilson's microscopic examination of wheat-straw grown on land which had been treated with infusorial earth. The substance of Prof. Wilson's paper we gave in the September number of the MONTHLY. Prof. Phin reproduces Wilson's engraved representation of the diatom forms said to have been found in the remains of the straw after treatment with nitric acid, and says: "A single glance at the engraving is sufficient to convince any microscopist that Prof. P. B. Wilson never saw 'upon the field of his microscope,' under the circumstances which he has described, the objects which he has delineated. . . . Bearing in mind that these organisms, as figured, have been obtained by destroying the organic matter with nitric acid, we find *Bacillaria* figured as it exists only in the living condition—the frustules being joined together in the peculiar way which has given to this form the specific name *paradoxa*. For this diatom to have passed through a bath of nitric acid, and come out in the condition figured, would have been almost as great a miracle as the passing of Shadrach, Meshach, and Abednego, unscathed through the fiery furnace of Nebuchadnezzar. So, too, we find a *calcareous* foraminifer figured under the same circumstances. After such instances, the numerous minor features which are utterly irreconcilable with facts may be safely passed over."

Another Way of securing the Chestnuts.—The following narrative is taken from the *Chronique de la Société d'Acclimation;* we give it for what it is worth: "A Frenchman, fifteen years resident in the Transvaal Republic, where he has established a number of plantations, recounts to us the following fact, which no naturalist has as yet reported: The coffee-plantations are much exposed to the ravages of the great cynocephalous monkeys. Among the coffee-plants there grows a shrub, the scientific name of which I have not been able to ascertain, which has its fruit growing very near the trunk. Some wasps, of a kind whose sting is very painful, had chosen several of these bushes for attaching to them their eggs, and the cynocephali were often seen eying the fruit very eagerly, but they dared not touch them for fear of the wasps. One morning, the planter heard terrible cries, and with the aid of a good opera-glass was enabled to witness an interesting spectacle. A fat old monkey, the leader of the troop, would take hold of the young ones, and pitch them repeatedly into the middle of the bush, despite their cries and groans. The shock brought down the wasps' nests, and the irate insects attacked the victims; meanwhile the old rogue quietly ate the fruit, throwing down the remnants of the meal to the females and young ones on the ground."

Taking Impressions of Plants.—M. Bertot, of the Paris Academy of Sciences, offers a simple method of taking impressions of plants. A sheet of paper is first lightly oiled on one side, then folded in four, so that the oil may filter through the pores, and the plant may not come into direct contact with the liquid. The plant is placed between the leaves of the second folding, and in this position pressed (through other paper) all over with the hand, so as to make a small quantity of oil adhere to its surface. Then it is taken out and placed carefully on white paper; another sheet is placed above, as two impressions can be taken at once, and the plant is pressed as before. On now removing it, an invisible image remains on the paper. Over this you sprinkle powdered black-lead, which causes the image to appear. With an assortment of colors, the natural colors of plants may be reproduced. To obtain fixity, resin is mixed with the black-lead in small quantity; the impression is fixed when it is exposed to a heat sufficient to melt the resin.

Ancient Weapons.—Among the Michigan exhibits of ancient stone and copper implements at the Philadelphia Exposition is a weapon fashioned after the model of the "patu-patu" of New Zealand. It is described by Dr. C. C. Abbott, in the *American Naturalist*. The patu-patu of New Zealand is, according to Tylor, quoted by Dr. Abbott, "an edged club of bone or

stone," in shape "like a soda-water bottle with the bulb flattened. It is a very effective weapon," he adds, "in a hand-to-hand fight, being so sharp that a man's skull may be split at one blow with it." The Michigan specimen is $16\frac{1}{4}$ inches long. It is $2\frac{5}{8}$ inches wide for 11 inches; then it tapers to $1\frac{1}{2}$ inch, but again widens to 2 inches at the end, thus forming a terminal knob. The edges are beautifully wrought, and are as sharp now as most of the polished stone axes and celts. In the vast collection of relics of American aborigines at Philadelphia Dr. Abbott finds no other specimen of the form here described, and it is presumable that this weapon was one seldom fashioned in North America.

NOTES.

A meeting of persons interested in the formation of a Metrological Society was lately held in Boston, which resulted in the organization of the "American Metric Bureau." Arrangements were made to secure a large list of honorary or life members, and to solicit subscriptions to supply teachers with metric apparatus at half-price. The assessment for 1876 was fixed at $2.50. The list of directors is as follows: Samuel W. Mason, J. P. Putnam, Prof. W. F. Bradbury, Dr. Edward Wigglesworth, Melvil Dewey, Prof. William Watson, Dr. H. P. Bowditch, S. S. Greene, Nathan Appleton, and Prof. K. S. Pennell.

In the Paris School of Mines is a laboratory, founded in 1845, for analyzing gratuitously any substances presented. Last year 767 analyses were made at this laboratory, chiefly of minerals and manures. A laboratory for the gratuitous analysis of medicines and articles of food would be a very useful institution in our American cities.

Cremation of the dead is now fairly established in Saxe-Gotha. In a recent sitting of the town council, it was decided to erect the necessary apparatus in the new cemetery. Cremation is to take place only in accordance with the clearly expressed wish of the deceased, and under permit from the proper medical officer. The ashes are to be gathered in urns, to be preserved by the family of the deceased, or set up in a hall in the cemetery.

In one of the monthly reports of the Department of Agriculture, it is stated that in Livingston County, Illinois, the planting of trees in groves and shelter-belts, and for ornamental purposes, is now very general. The black-walnut is the favorite tree for profit and ease of cultivation; but elm, soft maple, willow, cottonwood, European larch, and ash, are common, while evergreens are popular for ornamental purposes, and occasionally are planted in groves and shelter-belts.

At the Agricultural Congress in Philadelphia, resolutions were offered by Prof. C. V. Riley, and unanimously adopted, in favor of government action for the suppression of the Rocky Mountains locust-plague. In the opinion of the Congress, the national Legislature owes it to the people of the West to take this matter into consideration, and the United States are called upon to follow the example of other nations under like circumstances, and appoint a special commission for the thorough investigation of the subject.

In a work on the "Voices of Animals," by Landois, additional evidence is collected of the universality of vocal sounds among the lower animals, including the Mollusca. The author considers it to be indisputable that ants possess a vocal speech, by which they are enabled to exercise those higher mental faculties to which they owe their high social organization.

The University of Michigan had last year 101 female students, distributed as follows: Medicine, 37; law, 2; homœopathy, 2; literature, 60. "The experience of the past year," writes the president of the university in his annual report, "confirms the opinion we have been led to form by the experience of former years, that women who come here in good health are able to complete our collegiate or professional course of study without detriment to their health."

Prof. Maurice Schiff, of Florence, has demonstrated that the non-edible mushrooms, "toadstools," contain a common poison, *muscarine*, and that its effects are counteracted by either atropine or daturine. Italian apothecaries now keep these drugs in the rural districts, where the consumption of the non-edible fungi is apt to occur. The hint is worthy of attention everywhere.

It has been affirmed that not less than four per cent. of all the coal-laden vessels that have left English ports during the last five years, for destinations south of the equator, have suffered either total or partial loss by the spontaneous ignition of their cargoes.

At the recent meeting of the British Association, Mr. Garner stated that he had found from measurements of brain capacity, and from casts of the interiors of skulls, that the size of the brain in the dog does not correspond very closely with the size of the animal. No dog has so large a brain as the wolf, nor one so small as the jackal. The brain of a Newfoundland dog is very little larger than that of a terrier. Prof. Macalister, of Dublin, gave an account of the brain of the celebrated greyhound "Master Macgrath." He had weighed the brain of many other dogs, but Master Macgrath's was the heaviest of all, and the convolutions were much more complex.

In a balloon-voyage from Cherbourg, in August, two French aëronauts, Moret and Durnof, observed with surprise, at a height of 1,700 metres, that the bottom of the sea was visible in detail, though that part of the British Channel must have a depth of 60 to 80 metres. The rocks and submarine currents appeared with great distinctness. It is suggested that this fact might be utilized, a means being afforded of giving accurate representations of the bottom for the benefit of navigators.

In the *Scientific Farmer* we find recorded the death of Prof. Dimond, of the New Hampshire Agricultural College. He, no doubt, died of overwork. In the Agricultural College he was Professor of Agriculture, Botany, and Chemistry, farm-superintendent and steward, and at the same time was Professor of Botany and Chemistry in Dartmouth College. It is stated that three men will be appointed to perform the duties recently performed by Prof. Dimond.

During the past year the French Association for the Advancement of Science expended the sum of 7,000 francs in aid of scientific research. Of this sum, 5,000 francs was granted to the astronomer Janssen, to help defray his expenses as a member of the expedition to observe the transit of Venus; and 2,000 francs to M. Chapelas-Coulvier-Gravier, to enable him to continue his observations of shooting-stars.

At one point on the margin of Lake Tanganyika (Central Africa), Captain Cameron saw large masses of coal. In the district adjoining Manyuema iron is plentiful: the people manufacture large quantities of iron, and many of the articles they make are beautifully finished.

Prof. H. N. Martin will lecture on animal physiology, in the John Hopkins University, Baltimore, on Tuesdays and Fridays during the winter. The lectures will be accompanied by instruction in the laboratory. After the spring vacation, Prof Martin will deliver a course of lectures on general biology, intended for elementary students. There will also be organized, during the latter part of the session 1876–'77, a short course of more advanced lectures on embryology.

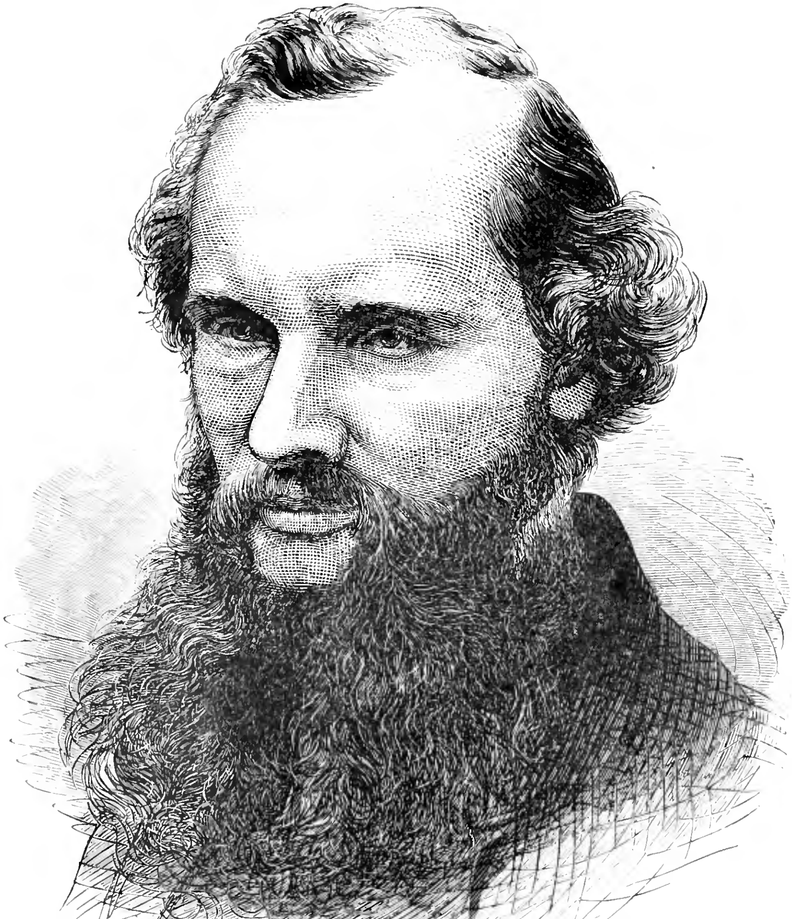
The formation of nickel-ore near Lancaster, Pennsylvania, is pronounced by the *American Manufacturer* to be the heaviest so far discovered in any part of the globe. The ore is exceedingly rich, of a grayish tint, very heavy, and so hard and closely united to the surrounding substances that it has to be got out by blasting. As soon as the ore is mined, it is crushed into small pieces, and then transferred to kilns of a capacity of from eighty to ninety tons each. It is then subjected to heat obtained at first by burning wood, and which is continued by the conversion of the evaporating fumes. The manipulation is concluded by the fused metal being placed in a smelting-furnace, and undergoing a process similar to that adopted in the treatment of iron-ore.

A Berlin machinist has invented a steam-velocipede. The boiler is heated by means of a petroleum-lamp, and rests on the axle of the hind-wheels.

The Paris correspondent of the London *Times* states that, in digging the new basin at St.-Nazaire, animal remains, tools, weapons, and utensils, have been found in a sandy stratum 20 feet below the surface. Last year a dolichocephalous skull was found near the same spot.

The Registrar-General of Great Britain and Ireland, in his quarterly return, states that the births of 296,350 children, and the deaths of 171,082 persons of both sexes, were registered in the United Kingdom in the three months ending June 30, 1876. The recorded natural increase of population was thus 125,268. The registered number of persons married in the quarter ending March 31, 1876, was 117,760. The resident population of the United Kingdom in the middle of 1876 is estimated at 33,093,439; that of England and Wales at 24,244,010, of Scotland at 3,527,811, and of Ireland at 5,321,618.

Dr. Magnus condemns the use of blue glasses as a protection for the eyes, and prefers the gray and smoky glasses used in England. He considers blue glass specially irritating to the eye, and says that many birds, reptiles, and amphibians, have yellow or reddish oil-drops in the eye to neutralize this blue color and protect the eyes.



SIR WILLIAM THOMSON.

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THE EARLIER FORMS OF LIFE.

By Professor C. H. HITCHCOCK,

STATE GEOLOGIST OF NEW HAMPSHIRE.

THE surmises and discoveries of the past twenty years have established the fact of the existence of life throughout the entire series of stratified rocks known to geologists, both sedimentary and metamorphic. When Principal Dawson published his description of the Eozoön in the Laurentian foundations, he was led to suggest the adoption of the term *Eozoic* in place of *Azoic* for all the ages older than Paleozoic, since, if life existed in the oldest formation, it must have continued to flourish in the following æons, even though evidences of its presence had not then been accumulated. Time has approved of this sagacious anticipation, and we can now maintain with serene confidence that the four great Eozoic periods—Laurentian, Labrador, Atlantic or Montalban, and Huronian—were all enlivened by the existence of both vegetable and animal life. And Eozoic life had its peculiar characteristics just as much as the Silurian or Carboniferous.

This life has appeared in consonance with the general principles of evolution as announced by our most learned sages. The earliest organic forms were the simplest in their structural relations; and they flourished through untold ages. The world was no longer young when the organic scheme permitted the growth of Cambrian trilobites and mollusca. More than half of geological time had passed away during the reign of protozoans and fungi. This suggests the enunciation of a general principle, in perfect agreement with the doctrines of evolution: the simpler the predominating forms of life the longer the period. In the beginning of Nature's operations, time was the element of which lavish use was made. It has grown more valuable as the ages have passed on, and the perfected type of organic development in our period grudges the loss of a single moment of it.

The evidences of the earlier forms of life naturally divide them-

selves into two groups, or those relating to plants and animals, which we will consider in their natural order:

Evidences of Plant-Life.—An interesting evidence of the existence of vegetation in Eozoic times is derived from the presence of iron-ores, an argument first set forth by Sterry Hunt. The ores are first formed in the hydrated condition, and then lose their water by metamorphic agencies, becoming specular and magnetic, or the state in which the Laurentian irons are now known. Ores of iron are conceived to have been formed under similar conditions in all ages. At the present day they accumulate in swamps and low grounds in the condition of the hydrated peroxide (ferric), or bog-ore, oftentimes in company with manganese. The presence of organic vegetable matter is requisite in order to extract the iron from the rock or soil and effect its deposition. The metal present in slight amount in the soil is the insoluble ferric oxide, or the familiar condition of iron-rust. Water charged with soluble vegetable infusions, like that in swamps too full of the disagreeable extract of leaves, etc., to be palatable, has the power of dissolving ferric oxide. The process consists in the removal of a part of the oxygen by the vegetable compound, or deoxidation, when the compound becomes changed into the readily-soluble ferreous oxide. But this is not a stable compound in the presence of our atmosphere. The rejected oxygen is brought back again, and in its recombination takes water with it, producing the hydrated ferric oxide, which, being insoluble, is precipitated, and covers the ground on the bottom of the pool. On visiting almost any swamp at the present day, this reddish-brown coating of hydrated iron-rust may be seen abundantly. Where streams of water cause the swampy water to flow to lower regions, the iron compound is also conveyed in suspension, and in the course of a few years a thick deposit of ore is accumulated. Our New England ancestors used these beds for the manufacture of their pig-iron in localities where only the name now exists for the village, such as the Tamworth or Gilmanton Iron-Works. All tradition of the manufacture there has disappeared. The Katahdin Company, in Maine, however, and some others, still derive their ore-supplies from this bog-compound.

Our theory supposes that the principal iron-ores in every age of the world had their origin in this way. There is no other agent save this organic extract which produces iron-ore on a large scale at the present day; hence it is rational to explain the origin of ancient ferruginous beds in the same way. If we examine the formations in order, we find the very ores themselves obviously thus accumulated: 1. There are the early Tertiary limonite beds of Western New England, New Jersey, and Pennsylvania, still scarcely removed from the bog form, with the accompanying clays. 2. There are the older Carboniferous nodules and the celebrated Clinton hematites, differing from the limonites only by the absence of water. 3. The specular

Huronian ores of Lake Superior have the same composition as the Silurian deposits. Lastly, the Laurentian magnetites constitute the other extreme of the ferruginous series. Both the water and a part of the oxygen have disappeared, leaving a compound richer in metal, and therefore more highly prized by the smelter. The application of a gentle, continuous heat is adequate to explain the change of the limonites into hematites and magnetites.

The process of change may be seen in the manufacture of common bricks, or the purification of quartz for the production of glass. The blue clay becomes red when burned, because it parts with its water of composition; and likewise the small percentage of hematite in the quartz becomes magnetic on the application of heat, and, after pulverization, has the iron removed by magnets, so that the silica-flour may be perfectly pure, and not impart a green tint to the glass. It is not maintained that the native limonites have been converted into magnetites in precisely the way in which the same results have been accomplished artificially; but the manipulation of the manufactured products shows that the metamorphosis is a feasible process, and by no means of difficult accomplishment in Nature.

In a review of a report by the author, in which this theory of iron-ore origin is elucidated, Prof. Dana objects[1] to its value, because "carbonic acid, which does now some of the work of iron-transportation, may have done far more then," on account of its presence in the atmosphere in great abundance. No doubt exists as to the assistance afforded by carbonic acid in this work, but this fact only confirms the truth of our argument, since no chemist will allow that carbonic acid can remove the iron-rust from the soil without the help of some deoxidating agent, such as vegetation. The chemical change for which we require the presence of vegetation is the same, whether carbonic acid be involved or not. Indeed, an excellent authority for the form in which this change is effected is the professor's own treatise on mineralogy,[2] where he says, "The iron is transported in solution as a *protoxide* carbonate in carbonated waters, a sulphate, or as a salt of an organic acid." Each of these methods requires the presence of a deoxidating agent like vegetation; and nothing better has yet been suggested. The iron-ores produced by volcanic ejections are of very limited amount, and mingled with too much dead rock to be capable of utilization. Nor does the suggestion of the decomposition of pyrites by atmospheric agents to form limonite necessitate the origin of all iron-ores in that way.

Accepting the validity of the argument, it follows that vegetation must have been extremely abundant in the Laurentian and Huronian ages on account of the presence in them of enormous deposits of iron-ores, as on Lake Superior, in the Adirondacks, Missouri, etc. Some of the beds are hundreds of feet in thickness.

[1] *American Journal of Science*, iii., vol. ix., p. 223. [2] Fifth edition, p. 173.

The presence of graphite, or plumbago, in the Eozoic rocks is by many regarded as a still stronger argument for the former existence of vegetation. As graphite is nearly pure carbon, it is easy to believe that it has accumulated from the remains of plants. Greater changes have been effected in its mass through metamorphism than in the alterations of the ore-beds. No traces of vegetable structure have yet been detected in graphite, so that no evidence as to the nature of the earliest plants can be afforded from morphology.

Nature of the Eozoic Flora.—What species of vegetation can we imagine to have existed in these early periods? Possibly we may derive a hint as to its nature from the general course of plant-development in later ages, and assume that there has been a correspondence between the order in which the different classes have appeared and their successive stages of complexity of structure. The simpler forms should appear first; or, reversing the statement, if we find a succession of all the higher forms of growth in later times, it is reasonable to expect in the still earlier periods larger developments of the inferior cryptogams, such as now play a comparatively insignificant part in the economy of Nature. Their easy decomposition would prevent the preservation of their specific shapes as fossils.

To particularize, we have among the lower orders of terrestrial vegetation the lichens, by some thought to be the parent of the fungi and algæ, since they can be resolved into two different plants, a fungus parasitic upon an alga; the mushrooms, puff-balls, mildews, blight, or fungi; the hepaticæ, and mosses. Of aquatic vegetation there are the numerous protophytes, the diatoms, with their siliceous shells; the desmids, the coccoliths, with their lenticular calcareous disks; the nullipores and corallines, making calcareous incrustations; and the great family of Algæ, simple, branched, and confluent. These afford us abundant material from which we may reconstruct the Eozoic meadows, forests, and submarine carpets.

The present system of plants seems to have originated in the Cretaceous period. The older Mesozoic gives us the cycads and tree-ferns, like those of the Asiatic tropics. The Paleozoic formations furnish a unique assemblage of combined cryptogamous and phenogamic nature of types not now existing. Granting that the two divisions of the plant kingdom are of equal importance in the line of development, we find ourselves in Silurian times only half-way back to the starting-point. If the Cambrian should furnish us with representations of the mosses and lichens, we might expect in Eozoic times some of these, together with the protophytes, etc., in order to complete the systematic and orderly development of the plant kingdom in time. Furthermore, the later ages have afforded gigantic representations of the higher orders. Why, then, should not the Eozoic land have had its forests of mushrooms and arborescent lichens; its swamps of diatoms, confervæ, the charæ and desmids,

and enormous aquatic growth of algæ, coccoliths, nullipores, and corallines? If we grant that the parasitic fungi could not exist for want of their proper organic food of higher organization, there are still enough forms remaining to take their place, and thus afford us a symmetrical development of all the phases of vegetable growth in the enormous periods when the simplest organic structures ruled the world.

EVIDENCES OF ANIMAL LIFE.—It has been argued by high authority that the existence of carbonate and phosphate of lime suggests the presence of animal life in the Laurentian seas, because at the present day these mineral substances are principally derived from organic secretions. The graphite may also have been partly of animal derivation. There is as much carbon in the Laurentian as in the Paleozoic Carboniferous. But these indications need not be dwelt upon, since recent discoveries have brought to light the actual relics of protozoans preserved in stones of Laurentian age. These are so convincing that the discussion of probabilities derived from rocks of supposed organic origin need not be dwelt upon. The organism has the name *Eozoön Canadense*, the *dawn-animal*, inhabiting the Canadian district.

Several names are connected with the discovery of this *Eozoön* from Ontario and elsewhere. Dr. Wilson, of Perth, sent specimens of it many years since to Sir William E. Logan, Director of Canadian Geological Survey, in which Dr. Sterry Hunt found a new hydrous silicate, which he called Loganite. In 1858 J. McMullen brought specimens which reminded Logan of the *Stromatopora* of the Silurian. They were examined by various scientists, and in 1865 a composite paper upon the geology, paleontology, and mineralogy of the fossil appeared in the journal of the Geological Society of London, prepared by Messrs. Logan, Dawson, Carpenter, and Hunt. Soon after Vennor discovered other specimens in the Montalban of Tudor, Ontario; Gümbel recognized it in both the Laurentian and Huronian in Bavaria; Bicknell and Burbank discovered it in Laurentian limestones at Newbury and Chelmsford, Massachusetts; and Edwards described it from the Adirondacks in New York. Scientists have not universally accepted the genuineness of this fossil. I will endeavor to present a brief sketch of the nature of the organism before stating their objections.

This animal structure belongs to the subkingdom Protozoa, a unique and inferior group of organisms. These animals are distinguished by possessing no alimentary cavity, or, if a stomach be present, it is not bounded by any walls. The three divisions, using the classification adopted by Dawson, are: the *Rhizopods*, *Sponges*, and *Infusoria*. The first is the lowest, including all the sarcodous animals whose only external organs are pseudopodia. The rhizopods are divided into the *Reticularia* or *Foraminifera*, possessing thread-

like and reticulating pseudopodia with granular matter instead of a nucleus, and with calcareous, membranous, or arenaceous skeletons; the *Radiolaria* and *Lobosa*, the first being the lowest, and embracing Eozoön. The reticularia may be still further divided into two sub-orders, *Perforata* and *Imperforata*, the first having calcareous skeletons penetrated with pores. This is the higher one, and holds Eozoön. Of the three families *Nummulinidæ*, *Globigerinidæ*, and *Lagundæ*, Eozoön belongs to the first and the highest in rank. It is not strictly, then, the lowest of the animal kingdom, though very near to it.

Fig. 1 shows several species of the foraminifera.

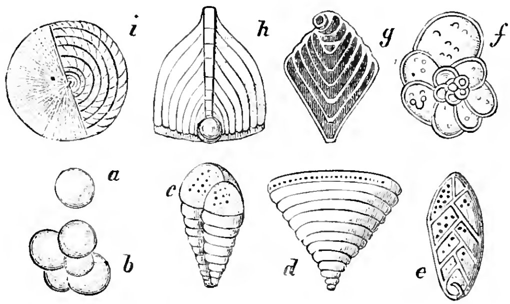


FIG. 1.—RHIZOPODS.

a, Orbulina universa; *b*, Globigerina rubra; *c*, Chrysalidina gradata; *d*, Cuneolina pavonia; *e*, Grammostomum phyllodes; *f*, Rotalia globosa; *g*, Flabellina rugosa; *h*, Frondicularia annularis; *i*, Nummulites nummularia.

The animal part of the rhizopods is a gelatinous body called sarcode, a bit of scarcely-organized protoplasm. Food is taken in through the outer wall, and is made into small pellets, which are surrounded by a digestive fluid in extemporized stomachs. Minute granules move about the interior, perhaps the substitute for a circulating fluid; and the outer wall can be moulded into the long processes called pseudopodia, used for locomotion and prehension. When these rhizopods secrete stony matter for a covering, the interior is the same structureless mass; but the shells assume characteristic forms for the different varieties. The *Orbulina* consists of a single cell with one orifice, but permeated by numerous microscopic pores, through which the protoplasmic material can ooze and form the pseudopodia. In the *Globigerina* and other genera there are several cells agglutinated together, all communicating with one another. In many species the thin cell-wall is inadequate for the wants of the structure, and an additional growth or "supplementary skeleton" is added, traversed by tubes larger, longer, and more branched, than in the first. In the ocean these minute creatures swarm in astonishing numbers, and their remains accumulate at the bottom, commingled with a paste of still more minute coccoliths and calcareous *débris* to form the ooze brought up in the sounding-lead from the telegraphed plateau. When

this calcareous mixture becomes solidified it is the chalk which abounds in the Cretaceous formation of Europe, and makes up the nummulitic and orbitoidal limestones.

Fig. 2 is a close copy of a small slab of Eozoön, showing what are called the laminated, acervuline, and fragmental portions. The diagonal white line represents the course of a vein of calcite. The dark lines and marks correspond to the sarcode or animal matter of the animal, now consisting of serpentine. Calling the base of the

FIG. 2.—NATURE-PRINT OF EOZOÖN. (DAWSON.)

figure the ocean-floor, there may be said to grow upon it the gelatinous sarcode or dark mass. Upon it grew first the delicate calcareous shell, penetrated by the numerous minute orifices or tubuli, larger pores, and occasionally supports of perpendicular plates. Added to this is the supplemental skeleton without the minute tubuli, but traversed by branching canals. This whole skeleton is represented by the white mass next the dark base, consisting of calcite. These two layers or laminæ constitute the essential part of the structure, and all the numerous layers above are but repetitions of them. Each lamina may cover several inches square of surface at the bottom of the ocean, and perhaps diminish in size as the organism grew upward. In the sketch the layers are seen to grow thinner toward the top, as if the vital energy became exhausted by the demands made upon it, and the supplemental skeleton first disappears. Finally, we have a mass of rounded chambers irregularly piled up near the top, constituting the "acervuline" structure. We may suppose the growth arrested at this stage, and the sending forth of reproductive germs to found new colonies in the adjacent ground.

In Fig. 3 we have an enlarged restoration, after Dawson, of a portion of the Eozoön structure, which will enable us to better appreciate the several parts of the organism. The dark, granulated layers at the base and at intervals higher up constitute the chambers, and contain the sarcode or gelatinous animal matter. Immediately above and below each dark layer is the thin calcareous shell penetrated by the minute orifices or tubuli. The white spaces represent the supplementary skeletons traversed by the larger canals. At the summit the sarcode is developed into several pseudopodia or cilia, by means of which food is brought to be assimilated.

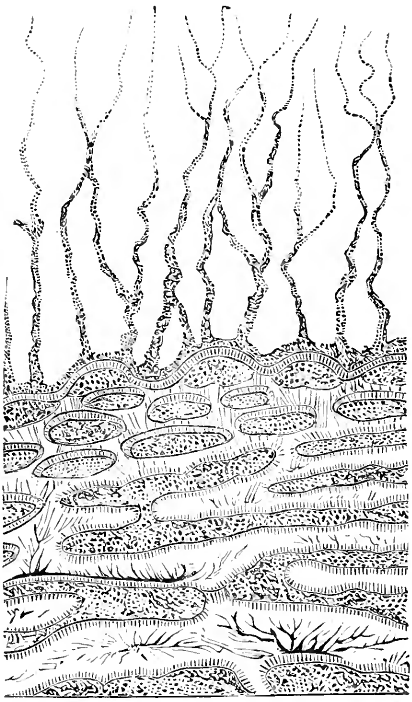


Fig. 3.—Eozoön restored. (After Dawson.)

In Fig. 4 we have a portion of Eozoön magnified one hundred diameters, drawn by Carpenter. The upper covering (*a a*) represents the original cell-wall penetrated by the tubuli or pores in great abundance. A bit of this is still more magnified in 2, by the side of the first, seemingly consisting of an upper and lower part. The greater part of the sketch consists of the supplemental or intermediate skeleton, traversed by two kinds of canals (*b*, *c*), of much larger size and greater irregularity than the tubulation of the cell-wall.

The arrangement and composition of the mineral matter of the Eozoön is quite interesting, and the more remarkable since it has

awakened hostile criticism and resulted in illustrating the presence of silicates in organisms in every age of the world. Formerly it was believed that carbonate of lime was the principal mineral found replacing organic substances, thus producing petrifactions. Now we have iron oxide, silica, clay, sand, sulphuret of iron, ores of copper, lead, etc., fluor-spar, heavy spar, phosphate of lime, all unmistakably occu-

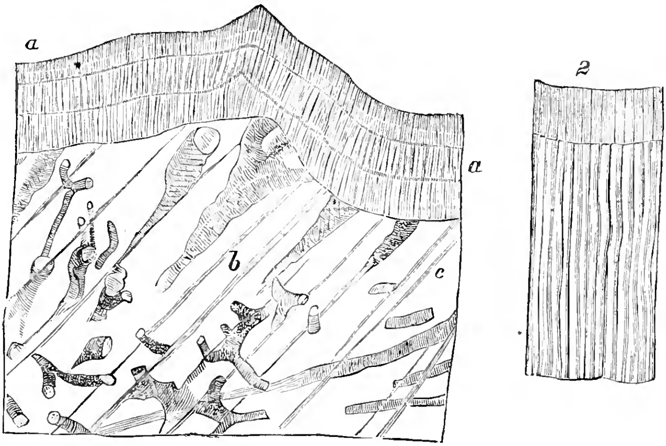


Fig. 4.—Portion of Eozoön magnified 100 Diameters. (After Carpenter.)
a a, Original cell-wall with tubulation; *b c*, Supplementary skeleton, with canals; 2. Portion of *a a* magnified.

pying the place of decomposable organic material. And the discussions about Eozoön recall and enforce facts about the employment of silicates by Nature to preserve her structures, especially in foraminiferal forms. In New Jersey there are beds of green-sand of Cretaceous and Tertiary ages full of concretions composed of a silicate of iron and potash called *glauconite.* Owing to its value as a fertilizer, thousands of tons of it are annually employed by the farmers to enrich their lands. This silicate has replaced modern organic structures of various kinds, but noticeably corals, echinoderms, nummulites, and other rhizopods. The fine tubulation and pores of these microscopic structures have been penetrated by the silicates, so that, when the calcareous parts have been removed by acid, the insoluble glauconite residue shows us the forms of the chambers and cavities. This process of the infiltration of organisms by glauconite was known long before the discovery of Eozoön. It goes on at the present day at the bottoms of the warmer seas, as evidenced in the facts discovered by the numerous deep-sea dredgings recently undertaken in the interests of science. Dr. Hunt suggests that the mineral is developed through chemical reactions in the ooze at the sea-bottom, a combination of dissolved silica with iron put into the ferrous soluble condition by means of organic matter.

Hydrous silicates act as mineralizers elsewhere than in the greensand. Crinoidal joints from the Silurian limestones of New Brunswick have been saturated by it, filling all the interstices, and small mollusks from Wales have had their interior permeated by it. There is much variation in the composition of these infiltrating silicates. Some from the *calcaire grossier*, near Paris, approach serpentine. Others carry magnesia. Those from the Lower Silurian of the Upper Mississippi Valley are like glauconite. In the Eozoön, as described above, serpentine, which is a hydrous silicate of magnesia, replaces the supposed sarcodous or animal part of the structure. It has thus corresponded to the glauconite of the present day filling the canals of the supplementary skeleton, the tubuli of the shell, and replacing the softer animal portions. Pyroxene and Loganite also replace the animal matter in the Canadian Laurentian fossils, and in the Eozoön discovered in the supposed Montalban series of Ontario carbonate of lime is the mineralizer. These last-named specimens were not described till 1867; and, as they exhibit the foraminiferal structure without the presence of any form of silicate, they completely establish the genuineness of the fossil. In Bavaria Gümbel states that chondrodite, hornblende, and scapolite, and perhaps other minerals, should be added to the list of silicates petrifying the Eozoön.

The objections that have been made to the organic character of Eozoön relate chiefly to the close resemblances between mineral and organic replacement, or between pseudomorphs and petrifactions. Other resemblances are to dendritic and concretionary structures. Inasmuch as these structures represent the higher efforts of the mineral kingdom in crystallization and the nearest approach to the inorganic world allowed by animal forms, it is not strange that the two extremes should resemble each other sufficiently to deceive practical observers. The canal system may be almost the very picture of certain dendrites. The latter, however, usually occupy a flat surface like moss-agates; whereas the former branch out in every direction, as appears in Fig. 5, projecting upward and downward, as well as sideways.

Organisms are preserved because of the more or less complete substitution of mineral for animal matter. Pieces of coal or wood that have been deposited in clay may be washed out, but the small pores and interstices will be seen to be filled with the matrix. When the burial has been in a solution capable of precipitating solid matter, the wood will be found more or less changed according to the nature of the solution and its capacity for alteration. Some specimens become nearly pure agate in consequence of the gradual substitution, particle by particle, of the organic matter by silica. Fig. 6 shows different stages of petrifaction in coniferous wood: *a* is a small fragment where the pores have been filled with silica, assuming a somewhat rhomboidal appearance, and the black parts represent the woody substance, still intact; in *b* the vegetable matter is wanting, having rotted away,

and only silica remains, the rhomboidal pieces being the only remnants of the original structure. The Eozoön has not been so completely fossilized as in the example of coniferous wood. The cell-wall and supplementary skeleton still retain much of the original lime, while the animal part has been entirely replaced by serpentine or some other mineral. Subsequent pressure or desiccation has produced cracks in the mass, which have been filled with an asbestus-like mineral of silky lustre, and this has sometimes been confounded with some part of the animal by objectors.

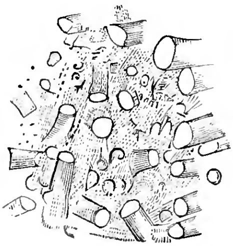


Fig. 5.—Canals of Eozoön, highly magnified.

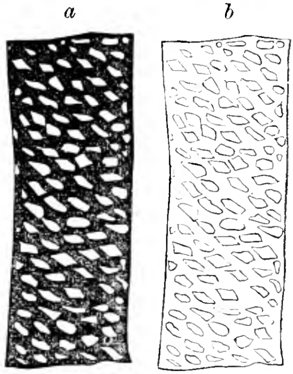


Fig. 6.—Coniferous Wood, illustrating Fossilization.

a, Partially mineralized, the white spaces being silica, the black vegetable matter; *b*, Vegetable matter removed by decomposition, leaving outline of the forms of the original pores.

Few special subjects have been so carefully studied as the genuineness of Eozöon. The treatises of Logan, Dawson, Carpenter, and Hunt, admirably set forth every possible phase of geological position, intimate zoölogical structure and affinity, mineral character both original and derived, and the conditions of origination. The elaborate papers of the objectors, Messrs. King, Rowney, Carter, Burbank, and others, show what the weaker positions are, and have enabled the advocates to satisfactorily fortify the less defensible points of their arguments. Every new discovery seems to aid the defenders, while the philosophy of evolution is in harmony with the existence of a long Eozoöic age where the predominant life is scarcely elevated above the working of crystalline forces.

Huronian Life.—Gümbel has described a species of Eozoön from the supposed Huronian rocks of Bavaria. In this country Billings has mentioned the occurrence of an *Aspidella* and *Arenicolites* from a series of Newfoundland rocks called "Intermediate," most probably of this age. The *Aspidella* bears some resemblance to the limpet-shell or *Patella*, while it may have been some variety of crustacean. The *Arenicolites* is a petrified worm-burrow.

But the specimens of greatest interest are those brought to light the present year by Mr. George W. Hawes from the Huronian of

New Hampshire.[1] The rocks have been carefully studied stratigraphically and lithologically, so that their place in the column is well understood, and the fossil is so allied to the Eozoön as to abundantly confirm all that has been held for it by its warmest advocates.

As a matter of convenience Mr. Hawes proposes to call the group of rocks affording these organisms *greenstones*, in allusion to their color. They have not been melted like a certain class of traps once called by this name, but have been metamorphosed somewhat; they embrace most of the chloritic and talcose schists, or, technically, "all basic metamorphic rocks whose predominant coloring ingredient is either hornblende, pyroxene, or chlorite." Those of special interest to us now are varieties of diorite and diabase, the first consisting mainly of hornblende and feldspar, the second adding labradorite to the constituents of the first-named rock. These rocks by many authors are regarded as of igneous origin.

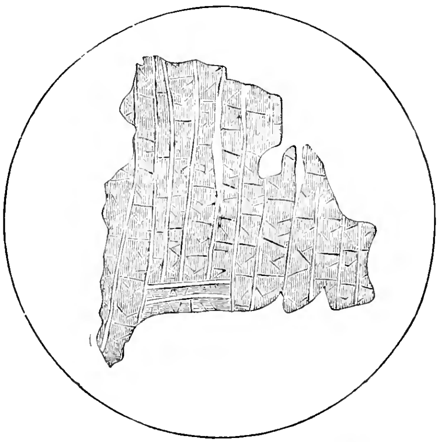


FIG. 7.—PROTOZOAN FOSSIL, PROBABLY STROMATOPORA, FROM CONNECTICUT LAKE, N. H.

The method of examination employed in determining the composition of these greenstones is of some interest. A bit of the specimen is carefully ground to the thinnest dimensions possible, so that it can be examined optically under the microscope. With common and polarized light it is possible to understand the nature of the minutest minerals present, as well as the cavities contained in them. The study of rocks in this way has been prosecuted so energetically of late, that it is common to speak of the sub-sciences micro-lithology, micro-petrology, etc., and the appearances of every mineral are now well understood by those skilled in observation, so that the conclusions are often more reliable than those obtained by ultimate chemical analysis. Mr. Hawes combines in his studies the use of the microscope and chem-

[1] *American Journal of Science*, iii., vol. xii., p. 134.

ical analysis, so that whatever cannot be determined in the one will be ascertained by the other method.

He was accordingly gratified to recognize in one of his rock-sections the fragment of a rhizopod. The structure has some resemblance to the acaleph *Chætetes*, but on account of the minuteness of the layers it should be classed with the rhizopods, reminding one very much of the *Stromatopora*. Figs. 7 and 8 illustrate these organisms magnified thirty-five diameters, thus making the breadth of the cells only $\frac{1}{280}$ of an inch. The smaller figure is probably a section of the

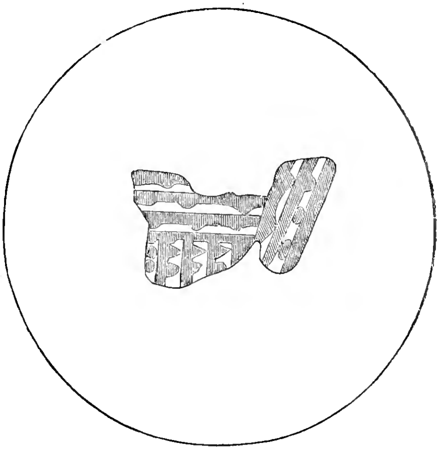


FIG. 8.—PROTOZOAN FOSSIL, FROM HANOVER, N. H.

same rhizopod, cut in a different direction. The rock holding these fossiliferous bits is diabase, a variety common between Connecticut Lake and Bellows Falls, both in New Hampshire and Vermont.

Since the naming of *Stromatopora* by Goldfuss fifty years since, naturalists have separated the acaleph structures from the true corals, but this genus is generally regarded as different from either of them. Prof. Hall described it as a polyp-coral in his "Paleontology of New York," but would not so regard it now. The most common form of it, as figured by him, is herewith presented (Fig. 9), from the Niagara limestone of Lockport, occurring in masses one or two feet in diameter. It is a protozoan coral, assisting in the work of reef-building, however, as much as the polyp-structures. By way of comparison we add a figure of a bryozoan mollusk (*Licheralia concentrica*), from the same formation and locality with the *Stromatopora* (Fig. 10). The relations of our new specimens are rather with the first of these forms, and will probably be described hereafter as species of *Stromatopora*.

It is an interesting fact that these "layer corals" have impressed the minds of all students of the Eozoön by their resemblances to the

dawn-animal. Logan speaks of it in his first remarks upon them, referring more particularly to their weathered outcrops and somewhat concentric structure; while Dawson sees much in their internal organization suggestive of a fitness for foraminiferal requirement. The layer seems better arranged for sheltering a gelatinous body, throwing out pseudopodia reaching after food, than for accommodating the

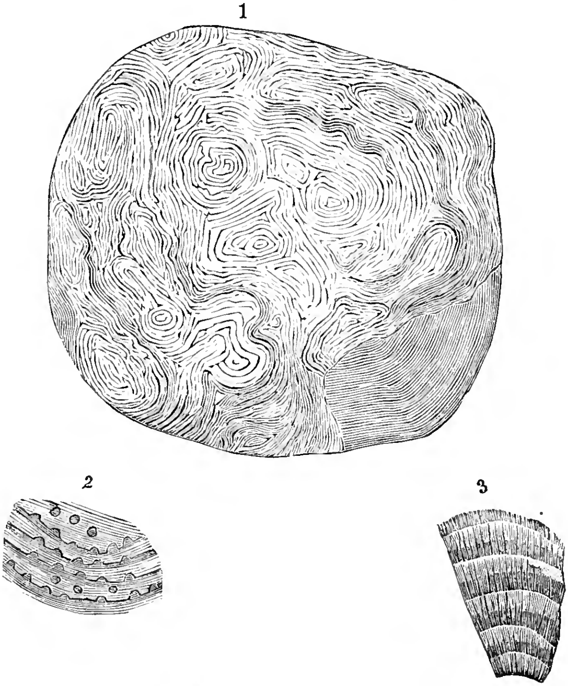


FIG. 9.—STROMATOPORA CONCENTRICA. (Goldf.)

1. Surface of a small hemispheric mass, showing the edges of the thin laminæ unequally weathered, natural size.
2. Magnified portion, showing weathered edges of successive laminæ, which are indented by pores.
3. More highly-magnified portion of the specimen, showing the walls and tubulation.

sponge animals, subsisting through the passage of currents of water. The canal system, with the supplemental skeleton, is wanting in this genus, but appears in the allied forms of the Devonian.

A very important feature of the greenstone fossils is their mineral composition. They are composed of silicates, very probably of feldspar. Mr. Hawes has not been able yet to satisfy himself fully as to the nature of the silicate, because of the smallness of the particles obtained. A drop of acid placed upon one of the specimens exhibited a slight effervescence, indicating the traces of carbonate of lime—perhaps part of the original foraminifer before its fracture and dispersion in the mud. He suggests that the presence of these lime-structures afforded the material for the manufacture of so much labradorite in the diabases containing the fossils.

I cannot forbear alluding to the interesting confirmation of the genuineness of Eozoön afforded by the discovery of these Huronian fossils in New Hampshire: 1. Eozoön sprung upon us with affinities rather remote from existing forms, but the *Stromatopora* has been known for fifty years as a veritable organism. 2. The latter has the same silicated condition with the former; hence we cannot set aside Eozoön merely because the supposed animal parts have been infiltrated

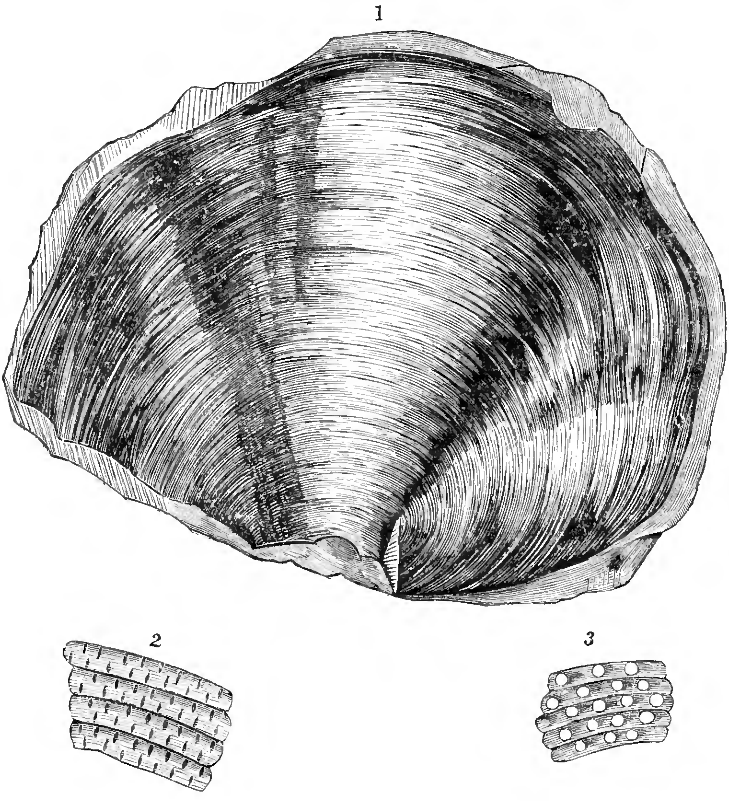


FIG. 10.—LICHENALIA CONCENTRICA. (Hall.)

1. A nearly perfect frond.
2, 3. Enlargements of the non-celluliferous side, showing the form and arrangement of the stigmata.

by a silicate. A well-known organism is proved to be silicated; hence all presumption against the existence of the same mineral condition in a related animal is removed. 3. *Stromatopora* is zoölogically allied to Eozoön. 4. It appears in a subsequent period, showing a natural order of development. 5. Stratigraphical and petrographical studies prove the greenstones to satisfactorily belong to the true Huronian formation, and thus make the sequence of life free from ambiguity.

EOZOIC GEOGRAPHY.—Such vast periods are necessarily involved in those early stages of the earth's growth, that we cannot portray

Eozoic scenery as a whole; while an artist would find material for only one sketch. At the first we must conceive of an earth with a larger diameter than is now accepted as the standard for the metric system of measures; of a shallow ocean covering the greater portion of the surface, interspersed with numerous islands, scattered everywhere without any method of arrangement that we understand. In the areas marked as Eozoic upon our maps, accumulations of strata were going on, of enormous thickness. We cannot recognize now the original land which supported the primeval vegetation, but can conjecture the boundaries of the contiguous oceans. In the latter part of the period the areas of deposition occupied basins situated within the limits of the earlier-formed rocks, being usually the deeper portions of the original oceans. Ridges between the water-basins resulted from the slow elevation of the land, the nuclei of great mountain-ranges, and there were ejections of melted matter, with marvelous alterations of sediments deep down beneath the surface.

Respecting the age as a whole, we may say that the waters were probably somewhat thermal, still simmering from the proximity of the heated interior; the air was thick and moist, partly composed of carbonic-acid gas; the sky was filled with dense clouds, marking the transition of day and night by periods of total darkness and seasons of feeble illumination, not permitting sunshine to cheer the vegetation. The life was characterized by its lowness of grade; the terrestrial plants hardly suitable for the food of air-breathing animals; the marine largely of the lime-secreting varieties and unicellular diatoms. The animals colonized the bottoms of the oceans, building up enormous reefs, but invisible to sight, if any one could have been permitted to look upon the infant world.

THEORIES OF PRIMITIVE MARRIAGE.[1]

By HERBERT SPENCER.

IN his ingenious and interesting work on "Primitive Marriage," the words "exogamy" and "endogamy" are used by Mr. McLennan to distinguish the two practices of taking to wife women belonging to other tribes, and taking to wife women belonging to the same tribe. As explained in his preface, his attention was drawn to these diverse customs by an inquiry into "the meaning and origin of the form of capture in marriage ceremonies;" an inquiry which led him to a general theory of early sexual relations. The following out-

[1] From advance-sheets of Spencer's "Principles of Sociology," Part "The Domestic Relations," chap. iv., "Exogamy and Endogamy."

line of his theory I disentangle, as well as I can, from statements that are not altogether consistent.

Scarcity of food led groups of primitive men to destroy female infants; because, "as braves and hunters were required and valued, it would be the interest of every horde to rear, when possible, its healthy male children. It would be less its interest to rear females, as they would be less capable of self-support, and of contributing, by their exertions, to the common good" (p. 165).

Mr. McLennan next alleges that "the practice in early times of female infanticide," "rendering women scarce, led at once to polyandry within the tribe, and the capturing of women from without" (p. 138).

Joined with a restatement of the causes we come upon an inferred result, as follows: "The scarcity of women within the group led to a practice of stealing the women of other groups, and in time it came to be considered improper, because it was unusual, for a man to marry a woman of his own group" (p. 289). Or, as he says on p. 140, "usage, induced by necessity, would in time establish a prejudice among the tribes observing it (exogamy)—a prejudice, strong as a principle of religion, as every prejudice relating to marriage is apt to be—against marrying women of their own stock."

To this habitual stealing of wives, and restealing of them, as among the Australians (p. 76), he ascribes that doubtful paternity which led to the recognition of kinship through females only. Though elsewhere admitting a more general cause for this primitive form of kinship (p. 159), he regards wife-stealing as its most certain cause, saying that "it must have prevailed wherever exogamy prevailed—exogamy and the consequent practice of capturing wives. Certainty as to fathers is impossible where mothers are stolen from their first lords, and liable to be restolen before the birth of children" (p. 226).

Assuming the tribes which thus grew into the practice of wife-stealing to have been originally homogeneous in blood, or at least to have supposed themselves so, Mr. McLennan argues that the introduction of wives who were foreigners in blood, joined with the rise of the first definite conception of relationship (that between mother and child) and consequent system of kinship exclusively in the female line, led to recognized heterogeneity within the tribe: there came to exist, within the tribe, children regarded as belonging by blood to the tribes of their mothers. Hence arose another form of exogamy. The primitive requirement that a wife should be stolen from another tribe, naturally became confounded with the requirement that a wife should be of the blood of another tribe; and hence girls born within the tribe, from mothers belonging to other tribes, became eligible as wives. The original exogamy, carried out only by robbing other tribes of their women, gave place, in part, or wholly, to the modified

exogamy carried out by marrying, from within the tribe, women bearing family names which implied that they were foreign in blood.

In tracing the development of higher forms of the domestic relations, Mr. McLennan postulates, as we have seen, that the scarcity of women "led at once to polyandry within the tribe, and the capturing of women from without." Describing and illustrating the different forms of polyandry, ending in that highest form in which the husbands are brothers, he points out that at this stage there arose recognition not only of descent in the female line, but also of descent in the male line; since the father's blood was known, if not the father.

Then through gradually-established priority of the elder brother, as being the first of the group to marry, and the first likely to have children, it became an accepted fiction that all the children were his: "the elder brother was a sort of *paterfamilias*;" and "the idea of fatherhood" thus caused was a step toward kinship through males, and "a step away from kinship through females" (pp. 243, 244).

Pointing out that among some polyandrous peoples, as the Kandians, the chiefs have become monogamists, Mr. McLennan argues (p. 245) that their example would be followed, and "thus would arise a practice of monogamy or of polygamy." And he thence traces the genesis of the patriarchal form, the system of agnation, the institution of caste.

Though this outline of Mr. McLennan's theory is expressed, whereever regard for brevity permits, in his own words, yet possibly he may take exception to it, for, as already hinted, there are incongruities in his statements, and the order in which they are placed is involved. That many of the phenomena he describes exist, is beyond question. It is undeniable that the stealing of women, still habitual with sundry low races, was practised in the past by races now higher; and that the form of capture in marriage ceremonies prevails in societies where no real capture occurs at present. It is undeniable that kinship through females is, among various primitive peoples, the only kinship avowedly recognized; and that it leads to the descent of name, rank, and property, in the female line. It is undeniable that in many places where wife-stealing is, or has been, the practice, marriage is forbidden between those of the same family name, who are assumed to be of the same stock. But while admitting much of the evidence, and while accepting some of the inferences, we shall find reason for doubting Mr. McLennan's theory taken as a whole. Let us consider, first, the minor objections.

Sundry facts inconsistent with his conclusion, though referred to by Mr. McLennan, he passes over as of no weight. He thinks there is warrant for the belief that exogamy and wife-capture have "been practised at a certain stage among every race of mankind" (p. 138): this stage being the one now exemplified by sundry low races. Nev-

ertheless, he admits that "the separate endogamous tribes are nearly as numerous, and they are in some respects as rude, as the separate exogamous tribes" (p. 145). Now, if, as he believes, exogamy and wife-stealing have "been practised at a certain stage among every race of mankind"—that stage being the primitive one—and if, as he seeks to prove, endogamy is a form reached through a long series of social developments, it is difficult to understand how the endogamous tribes can be as rude as the exogamous ones.

Again, he names the fact that "in some districts—as in the hills on the northeastern frontier of India, in the Caucasus, and the hill-ranges of Syria—we find a variety of tribes, proved, by physical characteristics and the affinities of language, of one and the same original stock, yet in this particular differing *toto cœlo* from one another—some forbidding marriage within the tribe, and some prescribing marriage without it" (pp. 147, 148): a fact by no means congruous with his hypothesis.

Should Mr. McLennan reply that on pp. 47, 48, he has recognized the possibility, or probability, that there were tribes primordially endogamous—should he say that on pp. 144, 145, will be found the admission that, perhaps, exogamy and endogamy "may be equally archaic," the rejoinder is that, besides being inconsistent with his belief that exogamy has "been practised at a certain stage among every race of mankind," this possibility is one which he practically rejects. On pp. 148–150, he sketches out a series of changes by which exogamous tribes may eventually become endogamous; and in subsequent sections on the "Growth of Agnation," and "The Rise of Endogamy," he tacitly asserts that endogamy has thus developed: if not without exception, still, generally. Indeed, the title of one of his chapters—"The Decay of Exogamy in Advancing Communities"—clearly implies the belief that exogamy was general, if not universal, with the uncivilized; and that endogamy grew up along with civilization. Thus the incongruity between the propositions quoted in the last paragraph cannot be escaped.

Sundry other of Mr. McLennan's statements and inferences conflict with one another. Assuming that, in the earliest state, tribes were stock-groups "organized on the principle of exogamy," he speaks of them as having "the primitive instinct of the race against marriage between members of the same stock" (p. 118). Yet, as we have seen above, he elsewhere speaks of wife-capture as caused by scarcity of women within the tribe; and attributes to this "usage, induced by necessity," the prejudice against "marrying women of their own stock." Moreover, if, as he says (and I believe rightly says) on p. 145, "men must originally have been free of any prejudice against marriage between relations," it seems inconsistent to allege that there was a "primitive instinct" "against marriage between members of the same stock."

Again, while in some places the establishment of the exogamous prejudice is ascribed to the practice of wife-stealing (pp. 53, 54, and 136), it is elsewhere made the antecedent of wife-stealing: interdict against marriage within the tribe was primordial. Now, if this last is Mr. McLennan's view, I agree with Sir J. Lubbock in thinking that it is untenable. It cannot be assumed that in these earliest groups of men, with which Mr. McLennan commences, there were any established rules of marriage. Unions of the sexes must have preceded all social laws. The rise of a social law implies a certain preceding continuity of social existence; and this preceding continuity of social existence implies the reproduction of successive generations. Hence reproduction, entirely unregulated by interdicts, must be taken as initial.

Assuming, however, that of his two views Mr. McLennan will abide by the more tenable one, that wife-stealing led to exogamy, let us ask how far he is justified in alleging that female infanticide, and consequent scarcity of women, led to wife-stealing. At first sight it appears undeniable that destruction of infant girls, if frequent, must have been accompanied by a deficiency of adult females; and it seems strange to call in question the legitimacy of this inference. But Mr. McLennan has overlooked a concomitant. Tribes in a state of chronic hostility are constantly losing their adult males, and the male mortality so caused is usually considerable. Hence the killing many female infants does not necessitate paucity of women: it may merely prevent excess. Excess must, indeed, be inevitable if, equal numbers of males and females being reared, some of the males are from time to time slain. The assumption from which Mr. McLennan's argument sets out is, therefore, inadmissible.

How inadmissible it is, becomes conspicuous on finding that, where wife-stealing is now practised, it is commonly associated with polygyny. The Fuegians, named by Mr. McLennan among wife-stealing peoples, are polygynists. According to Dove, the Tasmanians were polygynists, and Lloyd says that polygyny was universal among them; yet the Tasmanians were wife-stealers. The Australians furnish Mr. McLennan with a typical instance of wife-stealing and exogamy; and though Mr. Oldfield alleges scarcity of women among them, yet other testimony is quite at variance with his. Mitchell says: "Most of the men appeared to possess two [females], the pair in general consisting of a fat plump gin, and one much younger;" and, according to the Frenchman Peltier, named in the last chapter as having lived seventeen years with the Macadama tribe in Queensland, the women were "more numerous than the men, every man having from two to five women in his suite." In North America the Dakotas are at once wife-stealers and polygynists, Burton tells us. In South America the Brazilians similarly unite these two traits; and among the Caribs they are especially associated. Writing of polygyny as practised on

the Orinoco, Humboldt says: "It is most considerable among the Caribs, and all the nations that have preserved the custom of carrying off young girls from the neighboring tribes." How, then, can wife-stealing be ascribed to scarcity of women?

A converse incongruity also militates against Mr. McLennan's theory. His position is that female infanticide, "rendering women scarce, led at once to polyandry within the tribe, and the capturing of women from without." But polyandry does not, so far as I see, distinguish wife-stealing tribes. We do not find it among the above-named Tasmanians, Australians, Dakotas, Brazilians; and although it is said to occur among the Fuegians, and characterizes some of the Caribs, it is much less marked than their polygyny. Contrariwise, though it is not a trait of peoples who rob one another of their women, it is a trait of certain rude peoples who are habitually peaceful. There is polyandry among the Esquimaux, who do not even know what war is; there is polyandry among the Todas, who in no way aggress upon their neighbors

Other minor difficulties might be dwelt upon. There is the fact that in many cases exogamy and endogamy coexist, as among the Comanches, the New-Zealanders, the Lepchas, the Californians. There is the fact that in sundry cases polygyny and polyandry coexist, as among the Fuegians, the Caribs, the Esquimaux, the Warans, the Hottentots, the ancient Britons. There is the fact that there are some exogamous tribes who have not the form of capture in marriage, as the Iroquois and the Chippewas. But, not dwelling on these, I turn to certain cardinal difficulties, obvious *a priori*, which appear to me insuperable.

Setting out with primitive homogeneous groups, Mr. McLennan contends that the scarcity of women caused by destruction of female infants compelled wife-stealing; and he thinks that this happened "at a certain stage among every race of mankind" (p. 138). The implication is, therefore, that a number of adjacent tribes, usually belonging to the same variety of man in the same stage of progress, were simultaneously thus led to rob one another. But immediately we think of wife-stealing as a practice not of one tribe only, but of many tribes forming a cluster, there presents itself the question, How was the scarcity of women thus remedied? If each tribe had fewer women than men, how could the tribes get wived by robbing one another? The scarcity remained the same: what one tribe got another lost. Bearing in mind the low fertility and great infant mortality among savages, if there is a chronic deficiency of women and the tribes rob one another equally, the result must be diminished population in all the tribes. If some, robbing others in excess, get enough wives, and leave certain of the rest with very few, these must tend toward extinction. And if the surviving tribes carry on the process, there

appears no limit until the strongest tribe, continuing to supply itself with women from the less strong, finally alone survives and has no tribes to rob.

Should it be replied that female infanticide is, on the average of cases, not carried so far as to make the number of wives insufficient to maintain the aggregate population—should it be said that only exceptional tribes rear so few women as not to have mothers enough to produce the next generation—then we are met by a still greater difficulty. If in each of the exogamous tribes forming the supposed cluster the men are forbidden to marry women of their own tribe, and must steal women from other tribes, the implication is that each tribe knowingly rears wives for neighboring tribes, but not for itself. Though each tribe kills many of its female infants that it may not be at the cost of rearing them for its own benefit, yet it deliberately rears the remainder for the benefit of its enemies. Surely this is an inadmissible supposition. In proportion as the interdict against marrying women within the tribe is peremptory, the preservation of girls will be useless — worse than useless, indeed, since adjacent hostile tribes, to whom they must go as wives, will be thereby strengthened. And as all the tribes, living under like interdicts, will have like motives, they will all of them cease to rear female infants.

Manifestly, then, exogamy in its original form can never have been anything like absolute among the tribes forming a cluster, but can have been the law among some of them only.

In his concluding chapter Mr. McLennan says that, "on the whole, the account which we have given of the origin of exogamy appears the only one which will bear examination" (p. 289). It seems to me, however, that setting out with the postulate laid down by him, that primitive groups of men are habitually hostile, we may, on asking what are the concomitants of war, be led to a different theory, open to none of the objections above raised.

In all times and places, among savage and civilized, victory is followed by pillage. Whatever portable things of worth the conquerors find, they take. The enemies of the Fuegians plunder them of their dogs and arms; pastoral tribes in Africa have their cattle driven away by conquering marauders; and peoples more advanced are robbed of their money, ornaments, and all valuable things that are not too heavy. The taking of women is manifestly but a part of this process of spoiling the vanquished. Women are prized as wives, as concubines, as drudges; and, the men having been killed, the women are carried off along with the other movables. Everywhere among the uncivilized we find this. Turner tells us that "in Samoa, in dividing the spoil of a conquered people, the women were not killed, but taken as wives." We learn from Mitchell that in Australia, "on some whites telling a native that they had shot a man of another tribe, his only remark

was: 'Stupid white fellows! why did you not bring away the gins?'" And P. Martyr says that among the cannibal Caribs in his day "to eat women was considered unlawful. . . . Those who were captured young were kept for breeding, as we keep fowl, etc." Early legends of the semi-civilized show us the same thing; as when in the "Iliad" we read that the Greeks plundered "the sacred city of Eëtion," and that part of the spoils "they divided among themselves" were the women. And there need no examples to recall the fact that in later and more civilized times successes in battle have been followed by transactions allied in character, if not the same in form. Hence it is obvious that, from the beginning down to comparatively late stages, women-stealing has been an *incident* of successful war.

Observe, next, that the spoils of conquest, some of them prized for themselves, are some of them prized as trophies. Proofs of prowess are above all things treasured by the savage. He brings back his enemy's scalp, like the North American Indian. He dries and preserves his enemy's head, like the New-Zealander. He fringes his robe with locks of hair cut from his slain foe. Among other signs of success in battle is return with a woman of the vanquished tribe. Beyond her intrinsic value she has an extrinsic value. Like a native wife, she serves as a slave; but, unlike a native wife, she serves also as a trophy. As, then, among savages, warriors are the honored members of the tribe—as among warriors the most honored are those whose bravery is best shown by achievements—the possession of a wife taken in war becomes a badge of social distinction. Hence members of the tribe thus married to foreign women are held to be more honorably married than those married to native women. What must result?

In a tribe not habitually at war, or not habitually successful in war, no decided effect is likely to be produced on the marriage customs. If the great majority of the men have native wives, the presence of a few whose superiority is shown by having foreign wives will fail to change the practice of taking native wives: the majority will keep one another in countenance. But if the tribe, becoming more successful in war, robs adjacent tribes of their women more frequently, there will grow up the idea that the now-considerable class having foreign wives form the honorable class, and that those who have not proved their bravery by bringing back these living trophies are dishonorable: non-possession of a foreign wife will come to be regarded as a proof of cowardice. An increasing ambition to get foreign wives will therefore arise; and as the number of those who are without them decreases, the brand of disgrace attaching to them will grow more decided; until, in the most warlike tribes, it becomes an imperative requirement that a wife shall be obtained from another tribe—if not in open war, then by private abduction.

A few facts showing that by savages proofs of courage are often

required as qualifications for marriage, will carry home this conclusion. Herndon tells us that among the Mahués a man cannot take a wife until he has submitted to severe torture. Bates, speaking of the Passés on the Upper Amazons, says that formerly "the young men earned their brides by valiant deeds in war." Before he is allowed to marry, a young Dyak must prove his bravery by bringing back the head of an enemy. Bancroft quotes Colonel Cremony as saying that when the Apache warriors return unsuccessful, "the women turn away from them with assured indifference and contempt. They are upbraided as cowards, or for want of skill and tact, and are told that such men should not have wives." That, among other results of sentiments thus exemplified, abduction of women will be one, is obvious; for a man who, denied a wife till he has proved his courage, steals one, satisfies his want and achieves reputation at the same time. If, as we see, the test of deserving a wife is in some cases obtainment of a trophy, what more natural than that the trophy should often be the stolen wife herself? What more natural than that where many warriors of the tribe are distinguished by stolen wives, the stealing of a wife should become the required proof of fitness to have one? Hence would follow a peremptory law of exogamy.

In so far as it implies that usage grows into law, this interpretation agrees with that of Mr. McLennan. It does not, however, like his, assume either that this usage originated in a primordial instinct, or that it resulted from scarcity of women caused by infanticide. Moreover, unlike Mr. McLennan's, the explanation so reached is consistent with the fact that exogamy and endogamy in many cases exist; and with the fact that exogamy often coexists with polygyny. Further, it does not involve us in the difficulty raised by supposing a peremptory law of exogamy to be obeyed throughout a cluster of tribes.

But can the great prevalence of the form of capture in marriage ceremonies be thus accounted for? Mr. McLennan believes that, wherever this form is now found, complete exogamy once prevailed. Examination will, I think, show that the implication is not necessary. There are several ways in which the form of capture naturally arises; or rather, let us say, it has several conspiring causes.

If, as we have seen, there still exist rude tribes in which men fight for possession of women, the taking possession of a woman naturally comes as a sequence to an act of capture. That monopoly which constitutes her a wife in the only sense known by the primitive man is a result of successful violence. Thus the form may originate from actual capture within the tribe instead of originating from actual capture without it.

Beyond that resistance to a man's seizure of a woman apt to be made by other men within the tribe, there is the resistance of the

woman herself. Sir John Lubbock expresses the opinion that female coyness is not an adequate cause for the establishment of the form of capture; and it may be that, taken alone, it does not suffice to account for everything. But there are reasons for thinking it an important factor. Here are some of them. Crantz tells us concerning the Esquimaux that, when a damsel is asked in marriage, she—

"directly falls into the greatest apparent consternation, and runs out-of-doors tearing her bunch of hair; for single women always affect the utmost bashfulness and aversion to any proposal of marriage, lest they should lose their reputation for modesty."

Like behavior is shown by Bushmen girls. When—

"a girl has grown up to womanhood without having previously been betrothed, her lover must gain her own approbation, as well as that of the parents; and on this occasion his attentions are received with an affectation of great alarm and disinclination on her part, and with some squabbling on the part of her friends."

Again, among the Sinai Arabs, says Burckhardt, a bride—

"defends herself with stones, and often inflicts wounds on the young men, even though she does not dislike the lover; for, according to custom, the more she struggles, bites, kicks, cries, and strikes, the more she is applauded ever after by her own companions." During the procession to the husband's camp, "decency obliges her to cry and sob most bitterly."

Of the Muzos, Piedrahita narrates that after agreement with the parents was made—

"the bridegroom came to see the bride, and staid three days caressing her, while she replied by beating him with her fists and with sticks. After these three days she got tamer, and cooked his meals."

In these cases, then, coyness, either real or affected for reputation's sake, causes resistance of the woman herself. In other cases there is joined with this the resistance of her female friends. We read of the Sumatran women that "both the bride and her female relatives make it a point of honor to prevent (or appear to prevent) the bridegroom from obtaining his bride." On the occasion of a marriage among the Araucanians, Smith tells us that "the women spring up *en masse*, and arming themselves with clubs, stones, and missiles of all kinds, rush to the defense of the distressed maiden. . . . It is a point of honor with the bride to resist and struggle, however willing she may be." And once more we learn from Grieve that when a Kamtchatkan "bridegroom obtains the liberty of seizing his bride, he seeks every opportunity of finding her alone, or in company of a few people, for during this time all the women in the village are obliged to protect her."

Here we have, I think, proof that one origin of the form of capture is feminine opposition—primarily of the woman herself, and secondarily of female friends who naturally sympathize with her. Though the manners of the inferior races do not imply much coyness, yet we

cannot suppose coyness to be wholly absent. Hence that amount of it which really exists, joined with that further amount simulated for reputation's sake, will make resistance, and consequently capture, natural phenomena. Moreover, since a savage makes his wife a slave, and usually treats her brutally, she has an additional motive for resistance.

Nor does forcible opposition proceed only from the girl and her female friends: the male members of her family also are likely to be opponents. A woman is of value not only as a wife, but also as a daughter; and all through, from the lowest to the highest stages of social progress, we find a tacit or avowed claim to her services by her father. It is so even with the degraded Fuegians: an equivalent in the shape of service rendered has to be given for her by the youth, "such as helping to make a canoe." It is so with numerous more advanced savages all over the world: there is either the like giving of stipulated work, or the giving of a price. And we have evidence that it was originally so among ourselves: in an action for seduction the deprivation of a daughter's services is the injury alleged. Hence it is inferable that in the rudest states, where claims, parental or other, are but little regarded, the taking away of a daughter is likely to become the occasion of a fight. Facts support this conclusion. Of the Araucanians Smith tells us that, when there is opposition of the parents, "the neighbors are immediately summoned by blowing the horn, and chase is given." "Among the Gándors, a tribe on the southern shores of the Caspian Sea, the bridegroom must run away with his bride, although he thereby exposes himself to the vengeance of her parents, who, if they find him within three days, can lawfully put him to death." And we read concerning the Gonds that "a suitor usually carries off the girl that is refused to him by the parents." Thus we find a further natural cause for the practice of capture—a cause which must have been common before social usages were well established. Indeed, on reading that among the Mapuchés the man sometimes "lays violent hands upon the damsel, and carries her off," and that "in all such cases the usual equivalent is afterward paid to the girl's father," we may suspect that abduction, spite of parents, was the primary form; that there came next the making of compensation to escape vengeance; that this grew into the making of presents beforehand; and that so resulted eventually the system of purchase.

If, then, within a tribe there are three sources of opposition to the appropriation of a woman by a man, it does not seem that the form of capture is inexplicable unless we assume the abduction of women from other tribes.

But even supposing it to have originated in the capture of foreign women, its survival as a form of marriage would not prove exogamy to have been the law. In a tribe whose warriors had many of them wives taken from enemies, and who, as having captured their wives,

were regarded as more honorably married than the rest, there would result an ambition, if not to capture a wife, still to seem to capture a wife. In every society the inferior ape the superior; and customs thus spread among classes, the ancestors of which did not observe them. The antique-looking portraits that decorate many a modern, large house, by no means demonstrate the distinguished ancestry of the owner; but may merely simulate a distinguished ancestry. The coat of arms a wealthy man bears does not necessarily imply descent from men who once had their shields and flags covered by such marks of identity. The plumes borne on a hearse do not prove that the dead occupant had forefathers who wore knightly decorations. And, similarly, it does not follow that all the members of tribes who go through the form of capturing their wives at marriage are descendants of men who in earlier days actually captured their wives. Mr. McLennan himself points out that, among sundry ancient peoples, captured wives were permitted to the military class, though not to other classes. If we suppose a society formed of a dominant military class, originally the conquerors, who practised wife-capture, and a subject class who could not practise it—and if we ask what would happen when such a society fell into more peaceful relations with adjacent like societies, and obtained wives from them no longer by force, but by purchase or other friendly arrangement—we may see that, in the first place, the form of capture would replace the actuality of capture in the marriages of this dominant class; for, as Mr. McLennan contends, conformity to ancestral usage would necessitate the simulation of capture after actual capture has ceased. And when, in the dominant class, wife-capture had thus passed into a form, it would be imitated by the subject class as being the most honorable form. Such among the inferior as had risen to superior social positions would first adopt it; and they would gradually be followed by those below them. So that, even were there none of the other probable origins named above, a surviving form of capture in any society would not necessarily show that society to have been exogamous, but would merely show that wife-capture was in early times practised by its leading men.

And now, pursuing the argument, let us see whether exogamy and endogamy are not simultaneously accounted for as correlative results of the same differentiating process. Setting out with a state in which the relations of the sexes were indefinite, variable, and determined by the passions and circumstances of the occasion, we have to explain how exogamy and endogamy became established, the one here, the other there, as consequences of surrounding conditions. The efficient conditions were the relations to other tribes, now peaceful but mostly hostile, some of them strong, and some of them weak.

Necessarily, a primitive group not commonly at war with neighboring groups must be endogamous; for the taking of women from

other tribes is either a sequence of open war, or is an act of private war which brings on open war. Pure endogamy, however, resulting in this manner, is probably rare, since the hostility of tribes is almost universal. But endogamy is likely to characterize not peaceful groups alone, but also groups habitually worsted in war. An occasional abducted woman taken in reprisal will not suffice to establish in a weak tribe any precedent for wife-capture; but, contrariwise, a member of such a tribe who carries off a woman, and so provokes vengeance by the stronger tribe robbed, is likely to meet with general reprobation.[1] Hence marrying in the tribe will not only be habitual, but there will arise a prejudice, and eventually a law, against taking wives from other tribes; the needs of self-preservation will make the tribe endogamous. This interpretation harmonizes with the fact, admitted by Mr. McLennan, that the endogamous tribes are as numerous as the exogamous; and also with the fact he admits, that in sundry cases clusters of tribes allied by blood and language are some of them exogamous and some endogamous.

It is to be inferred that, among tribes not differing much from one another in strength, there will be continual aggressions and reprisals, accompanied by mutual robberies of women. No one of them will be able to supply itself with wives entirely at the expense of adjacent tribes, and hence, in each of them, there will be both native wives, and wives taken from other tribes—there will be both exogamy and endogamy. Stealing of wives will not be reprobated, because the tribes robbed are not too strong to be defied; and it will not be insisted on, because the men who have stolen wives will not be numerous enough to determine the average opinion.

If, however, in a cluster of tribes, one gains predominance by frequent successes in war—if the men in it who have stolen wives come to form the larger number—if the possession of a stolen wife becomes a mark of that bravery without which a man is not worthy of a wife—then the discreditableness of marrying within the tribe, growing into disgracefulness, will end in a peremptory requirement to get a wife from another tribe—if not in open war, then by private theft: the tribe will become exogamous. A sequence may be traced. The exogamous tribe thus arising, and growing while it causes adjacent tribes to dwindle by robbing them, will presently divide; and its sections, usurping the habitats of adjacent tribes, will carry with them the established exogamous habit. When, presently becoming hostile, these diverging sub-tribes begin to rob one another of women, there will

[1] Since the above sentence was written, I have, by a happy coincidence, come upon a verifying fact, in the just-published "Life in the Southern Isles," by the Rev. Mr. Gill (p. 47). A man, belonging to one of the tribes in Mangaia, stole food from an adjacent tribe. This adjacent tribe avenged itself by destroying the houses, etc., of the thief's tribe. Thereupon the thief's tribe, angry because of the mischief thus brought upon them, killed the thief. If this happened with a stealer of food, still more would it be likely to happen with a stealer of women, when the tribe robbed was the more powerful.

arise conditions conducive to that internal exogamy which Mr. McLennan supposes, rightly I think, to replace external exogamy. For, unless we assume that, in a cluster of tribes, each will undertake to rear women for adjacent tribes to steal, we must conclude that the exogamous requirement will be met in a qualified manner. Wives born within the tribe, but foreign by blood, will, under pressure of the difficulty, be considered allowable, instead of actually stolen wives. And thus, indeed, that kinship in the female line, which primitive irregularity in the relations of the sexes originates, will become established, even though male parenthood is known; since this interpretation of kinship will make possible conformity to a law of *connubium* that could not otherwise be obeyed.

Nothing of much importance is to be said respecting exogamy and endogamy in their general bearings on social life.

Exogamy in its primitive form is clearly an accompaniment of the lowest barbarism; and it decreases as the hostility of societies becomes less constant, and the usages of war mitigated. That the implied crossing of tribal stocks, where these tribal stocks are very small, may be advantageous, physiologically, is true; and exogamy may so secure a benefit which at a later stage is secured by the mingling of conquering and conquered tribes; though none who bear in mind the thoughtlessness of savages will suppose such a benefit to have been contemplated. But the exogamous custom, as at first established, implies an extremely abject condition of women; a brutal treatment of them; an entire absence of the higher sentiments that accompany the relation of the sexes. Associated with the lowest type of political life, it is also associated with the lowest type of domestic life.

Evidently endogamy, which at the outset must have characterized the more peaceful groups, and which has prevailed as societies have become less hostile, is a concomitant of the higher forms of the family.

PROFESSOR HUXLEY'S LECTURES.[1]

III.

THE DEMONSTRATIVE EVIDENCE OF EVOLUTION.

In my last lecture, I had occasion to place before you evidence derived from fossil remains, which, as I stated, was perfectly consistent with the doctrine of evolution, in fact, was favorable to it, but could not be regarded as the highest kind of evidence, or as that sort of evidence that we call demonstrative.

[1] The last of three lectures on "The Direct Evidence of Evolution," delivered at Chickering Hall, New York, September 20th. From the report of the *New York Tribune*, carefully revised by Prof. Huxley.

I pointed out, in fact, that, as we go back in time, the great intervals which at present separate some of the larger divisions of animals become more or less completely obliterated by the appearance of intermediate forms, so that if we take the particular case of reptiles and birds, upon which I dwelt at length, we find in the mesozoic rocks animals which, if ranged in series, would so completely bridge over the interval between the reptile and the bird that it would be very hard to say where the reptile ends and where the bird begins. Evidence so distinctly favorable to evolution as this is far weightier than that upon which men undertake to say that they believe many important propositions; but it is not the highest kind of evidence attainable for this reason, that, as it happens, the intermediate forms to which I have referred do not occur in the exact order in which they ought to occur, if they really had formed steps in the progression from the reptile to the bird; that is to say, we find these forms in contemporaneous deposits, whereas the requirements of the demonstrative evidence of evolution demand that we should find the series of gradations between one group of animals and another in such order as they must have followed if they had constituted a succession of stages, in time, of the development of the form at which they ultimately arrive. In other words, the complete evidence of the evolution of the bird from the reptile—what I call the demonstrative evidence, because it is the highest form of this class of evidence; that evidence should be of this character, that in some ancient formation reptiles alone should be found; in some later formations birds should first be met with; and in the intermediate strata we should discover in regular succession those forms which I pointed out to you which are intermediate between reptiles and birds.

The proof of evolution cannot be complete until we have obtained evidence of this character, and that evidence has of late years been forthcoming in considerable and continually increasing quantity. Indeed, it is somewhat surprising how large is the quantity of that evidence, and how satisfactory is its nature, if we consider that our obtaining such evidence depends upon the occurrence in a particular locality of an undisturbed series deposited through a long period of time, which requires the further condition that each of these deposits should be such that the animal remains imbedded in them are not much disturbed, and are imbedded in a state of great preservation. Evidence of this kind, as I have said, has of late years been accumulating largely, and in respect to many divisions of the animal kingdom. But I will select for my present purpose only one particular case, which is more adapted to the object I have in view, as it relates to the origin, to what we may call the pedigree, of one of our most familiar domestic animals—the horse. But I may say that in speaking of the origin of the horse I shall use that term in a general sense as equivalent to the technical term *Equus*, and meaning not what you

ordinarily understand as such, but also asses and their modifications, zebras, etc. The horse is in many ways a most remarkable animal, inasmuch as it presents us with an example of one of the most perfect pieces of machinery in the animal kingdom. In fact, among mammals it cannot be said that there is any locomotive so perfectly adapted to its purposes, doing so much work with so small a quantity of fuel, as this animal—the horse. And, as a necessary consequence of any sort of perfection, of mechanical perfection as of others, you find that the horse is a beautiful creature, one of the most beautiful of all land-animals. Look at the perfect balance of its form, and the rhythm and perfection of its action. The locomotive apparatus is, as you are aware, resident in its slender fore and hind limbs; they are flexible and elastic levers, capable of being moved by very powerful muscles; and, in order to supply the engines which work these levers with the force which they expend, the horse is provided with a very perfect feeding apparatus, a very perfect digestive apparatus.

Without attempting to take you very far into the region of osteological detail, I must nevertheless—for this question depends upon the comparison of such details—trouble you with some points respecting the anatomical structure of the horse, and more especially with those which refer to the structure of its fore and hind limbs. But I shall only touch upon those points which are absolutely essential to the inquiry that we have at present put. Here is the fore-leg of a horse: The bone which is cut across at this point is that which answers to the upper-arm bone in my arm, what you would call the humerus. This bone corresponds with my forearm. What we commonly term the knee of the horse is the wrist; it answers to the wrist in man. This part of the horse's leg answers to one of the human fingers, and the hoof which covers this extended joint answers to one of my nails.

You observe that, to all appearance, there is only one bone in the forearm. Nevertheless, at the upper end I can trace two separate portions; this part of the limb, and the one I am now touching. But as I go farther down it runs at the back part into the general bone, and I cease to be able to trace it beyond a certain point. This large bone is what is termed the radius, and answers to the bone I am touching in my arm, and this other portion of bone corresponds to what is called the ulna. To all appearance in the forearm of the horse the ulna is rudimentary, and seems to be fused into one bone with the radius.

It looks thus as if the ulna, running off below, came to an end, and it very often happens in works on the anatomy of the horse that you find these facts are referred to, and a horse is said to have an imperfect ulna. But a careful examination shows you that the lower extremity of the ulna is not wanting in the horse. If you examine a very young horse's limb you will find that this portion of the bone I

am now showing you is separable from the rest, and only unites as the animal becomes older, and this is, in point of fact, the lower extremity of the ulna; so that we may say that in the horse the middle part of the ulna becomes rudimentary and unites with the radius, and that the lower extremity of the ulna is so early united with the lower extremity of the radius that every distinct trace of separation has vanished in the adult.

I need not trouble you with the structure of this portion that answers to the wrist, nor with a more full description of the singular peculiarities of the part, because we can do without them for the present, but I will go on to a consideration of the remarkable series of bones which terminates the fore-limb. We have one continuous series in the middle line which terminates in the coffin-bone of the horse upon which the weight of the fore-part of the body is supported. This series answers to a finger of my hand, and there are good reasons—perfectly valid and convincing reasons, which I need not stay to trouble you with—which prove that this answers to the third finger of my hand enormously enlarged.

And it looks at first as if there were only this one finger in the horse's foot. But, if I turn the skeleton round, I find on each side a bone shaped like a splint, broad at the upper and narrow at the lower end, one on each side. And those bones are obviously and plainly and can be readily shown to be the rudiments of the bones which I am now touching in my own hand—the metacarpal bones of the second and of the fourth finger—so that we may say that in the horse's fore-limb the radius and ulna are fused together, that the middle part of the ulna is excessively narrow, and that the foot is reduced to the single middle finger, with rudiments of the two other fingers, one on each side of it. Those facts are represented in the diagram I now show you of the recent horse. Here is the fore-limb (pointing to the diagram), with the metacarpal bones and the little splint-bones, one on each side. It sometimes happens that by way of a monstrosity you may have an existing horse with one or other of these toes—that is, provided with its terminal joints.

Let me now point out to you what are the characteristics of the hind-limb. This (pointing to the diagram) is the shin-bone of the horse, and it appears at first to constitute the whole of the leg. But there is a little splint at this point which is the rudiment of the small bone of the leg—what is called the fibula—and then there is connected with the lower end of the tibia a little nodule which represents the lower end of the fibula, in just the same way as that little nodule in the fore-limb represents the lower end of the ulna. So that in the leg we have a modification of the same character as that which exists in the fore-limb—the suppression of the greater part of the small bone of the leg and the union of its lower end with the tibia. So, again, we find the same thing if we turn to the remainder of the leg.

This (showing) is the heel of the horse, and here is the great median toe, answering to the third toe in our own foot; and here we have upon each side two little splint-bones, just as in the fore-limb, which represent the rudiments of the second and the fourth toes—rudiments, that is to say, of the metatarsal bones, the remaining bones having altogether vanished. Let me beg your attention to these peculiarities, because I shall have to refer to them by-and-by. The result of this modification is, that the fore and hind limbs are converted into long, solid, springy, elastic levers, which are the great instruments of locomotion of the horse.

As might be expected, and as I have already said, the apparatus for providing this machine with the fuel which it requires is also of a very highly differentiated character. A horse has, or rather may have, forty-four teeth, but it rarely happens that in our existing horses you find more than forty—for a reason which I will communicate directly—and in a mare it commonly happens that you find no more than thirty-six, because the "tushes," or canine teeth, of the mare are rarely developed. Then there are some curious peculiarities about these teeth. As every one who has had to do with horses knows, the cutting teeth—the incisors—are six above and six below, and those incisors present what is called a "mark;" at least, that mark is usually present in horses up to a certain age. It is a sort of dark patch across the middle of the tooth. The presence of that dark patch arises from a great peculiarity in the structure of the horse's incisor tooth. It is in fact considerably curved, with a deep pit in the middle of the crown, and then a long fang. In the young foal this pit is very deep. As the animal feeds, this pit becomes filled up with its fodder, that fodder becomes more or less carbonized, and then you have the dark mark, and the reason the dark mark serves as an indication of age, for, as the horse feeds, this is more and more worn down, until at last, in an aged horse, the tooth is worn beyond the bottom of the pit, and the mark disappears. Then, as I said, the male horse generally has canine teeth. We need not notice their structure particularly. Following that, you may occasionally notice a very small and rudimentary tooth, but it is very often absent. It really represents the first tooth of the grinding series. Then there follow six great teeth, with exceedingly long crowns. The crowns, in fact, are so long that the teeth take a very long time to wear down, whence arises the possibility of the great age to which horses sometimes attain. This is shown in the side diagram. Then the pattern and structure of a horse's tooth are very curious. The crown of the horse's tooth presents a very complicated pattern; that is to say, supposing this to be one of the grinders of the left side (illustrating) above, there is a kind of wall like a double crescent. Then there are two other crescents, which fall in that direction, and these are complicated by folds, and all the spaces between these crescentic ridges are filled up by a kind

of bony matter which is called cement. Consequently the surface of the tooth is composed of very uneven materials—of the hard mass of the tooth, which is called dentine, then a very much harder enamel, and a softer cement between, the practical effect of which is the same as the lamination of the millstone. In consequence of the lamination of the millstone the ridges wear less swiftly than the intermediate substance, and therefore the surface always keeps rough and exerts a crushing effect upon the grain. The same is true of the horse's tooth, and consequently the grinding of the teeth one against the other, instead of flattening the surface of the teeth, tends to keep them always irregular, and that has a very great influence upon the rapid mastication of the hard grain or the hay upon which the horse subsists.

I think that will suffice as a brief indication of some of the most important peculiarities and characteristics of the horse. If the hypothesis of evolution is true, what ought to happen when we investigate the history of this animal? We know that the mammalian type, as a whole—that mammalian animals—are characterized by the possession of a perfectly distinct radius and ulna, two separate and distinct movable bones. We know, further, that mammals in general possess five toes, often unequal, but still as completely developed as the five digits of my hand. We know further that the general type of mammal possesses in the leg, not only a complete tibia, but a complete fibula—a complete, distinct, separable bone. Moreover, in the hind-foot we find, in animals in general, five distinct toes, just as we do in the fore-foot. Hence it follows a differentiated animal like the horse must have proceeded by way of evolution or gradual modification from a form possessing all the characteristics we find in mammals in general. If that be true, it follows that if there be anywhere preserved in the series of rocks a complete history of the horse, that is to say of the various stages through which he has passed, those stages ought gradually to lead us back to some sort of animal which possessed a radius, and an ulna, and distinct complete tibia and fibula, and in which there were five toes upon the fore-limb, no less than upon the hind-limb. Moreover, in the average general mammalian type, the higher mammalian, we find, as a constant rule, an approximation to the number of forty-four complete teeth, of which twelve are cutting teeth, four are canine, and the others are grinders. In unmodified mammals we find the incisors have no pit, and that the grinding teeth, as a rule, increase in size from that which lies in front toward those which lie in the middle or at the hinder part of the series. Consequently, if the theory of evolution be correct, if that hypothesis of the origin of living things have a foundation, we ought to find in the series the forms which have preceded the horse, animals in which the mark upon the incisor gradually more and more disappears, animals in which the canine teeth are present in both sexes, and ani-

mals in which the teeth gradually lose the complications of their crowns and have a simpler and shorter crown, while at the same time they gradually increase in size from the anterior end of the series toward the posterior. Let us turn to the facts and see how they bear upon the requirements of this doctrine of evolution.

In what is called here the Pliocene formation, that which constitutes almost the uppermost division of the tertiary series, we find the remains of horses. We also find in Europe abundant remains of horses in the most superficial of all these formations—that is, the post-tertiary, which immediately lies above the Pliocene. But these horses, which are abundant in the cave-deposits and in the gravels of England and Europe—these horses, of which we know the anatomical structure to perfection—are in all essential respects like existing horses. And that is true of all the horses of the latter part of the Pliocene epoch. But in the earlier Pliocene and later Miocene epoch, in deposits which belong to that age, and which occur in Germany and in Greece, in India, in Britain, and in France, we find animals which are like horses in all the essential particulars which I have just described, and the general character of which is so entirely like that of the horse that you may follow descriptions given in works upon the anatomy of the horse upon the skeletons of these animals. But they differ in some important particulars. There is a difference in the structure of the fore and hind limb, and that difference consists in this, that the bones which are here represented by two splints, imperfect below, are as long as the middle metacarpal bone, and that attached to the extremity of each is a small toe with its three joints of the same general character as the middle toe, only very much smaller, and so disposed that they could have had but very little functional importance, and that they must have been rather of the nature of the dew-claws such as are to be found in many ruminant animals. This *Hipparion*, or European three-toed horse, in fact presents a foot similar to that which you see here represented, except that in the European *Hipparion* these smaller fingers are farther back, and these lateral toes are of smaller proportional size.

But nevertheless we have here a horse in which the lateral toes, almost abortive in the existing horse, are fully developed. On careful investigation you find in these animals that also in the fore-limb the ulna is very thin, yet is traceable down to the extremity. In the hind-limb you find that the fibula is pretty much as in the existing horse. That is the kind of equine animal which you meet with in these older Pliocene and later Miocene formations, in which the modern horse is no longer met with. So you see that the *Hipparion* is the form that immediately preceded the horse. Now let us go a step farther back to the middle and older parts of which are called the Miocene formation. There you find in some parts of Europe the equine animals which differ essentially from the modern horse, though

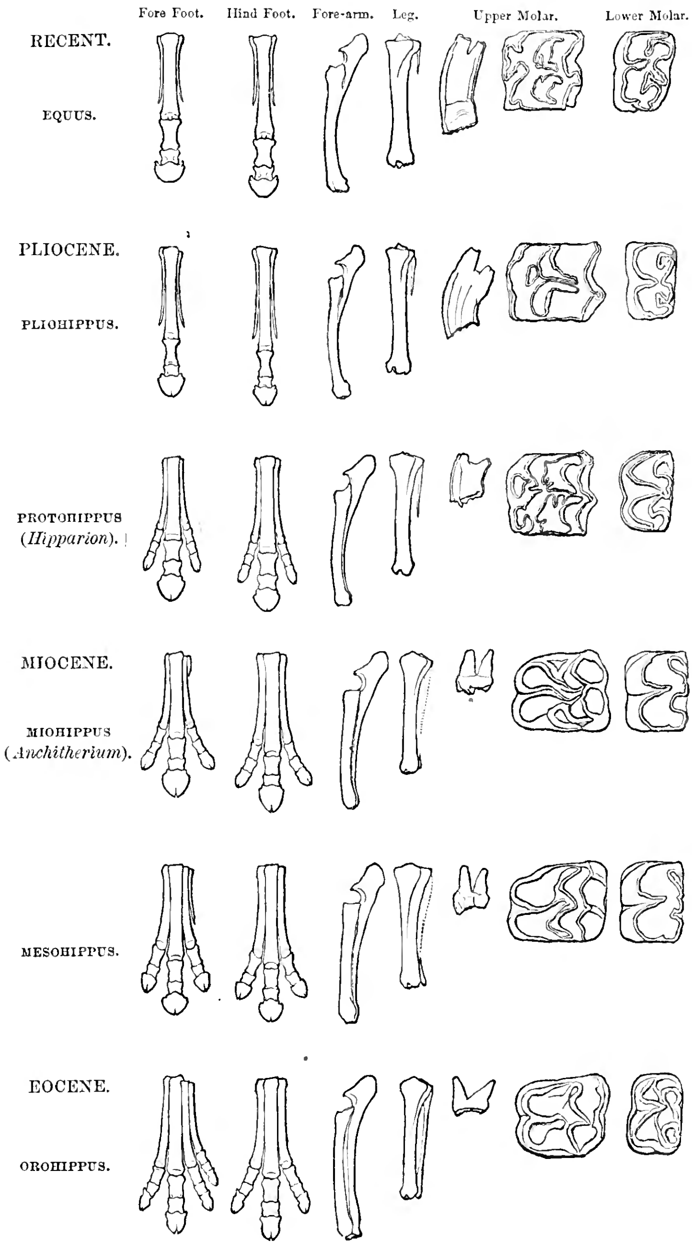
they resemble the horse in the broad features of their organization. They differ in the characters of their fore and hind limbs, and present important features of difference in the teeth. The forms to which I now refer are what constitute the genus *Anchitherium*. We have three complete toes; the middle toe is smaller in proportion, the inner and outer toes are larger, and in fact large enough to rest upon the ground, and to have functional importance—not an animal with two dew-claws, but an animal with three functional toes. And in the fore-arm you find the ulna a very distinct bone, quite readily distinguishable in its whole length from the radius, but still pretty closely united with it. In the hind-limb you also meet with three functional toes. The structure of the hind-foot corresponds with that of the fore-foot; but in the hind-leg the fibula is better developed. In some cases I have reason to think that it is complete; at any rate this lower end of it is quite distinctly recognizable. But the most curious change is that which is to be found in the character of the teeth. The teeth of the *Anchitherium* have, in the first place, so far as the incisors are concerned, a rudimentary pit. The canine teeth are present in both sexes. The molars are short; there is no cement, and the pattern is somewhat like this (drawing on the blackboard). In the upper jaw, there are two crescents and two oblique ridges, while in the lower jaw you have the double crescent. It is quite obvious that this (illustrating from drawing) is a simpler form than that. By increasing the complexity of those teeth there, we have the horse's teeth. These are all the forms with which we are acquainted respecting the past history of the horse in Europe. When I happened to occupy myself with this subject some years ago, notwithstanding certain difficulties, the facts left no doubt whatever in my mind that we had here a general record of the history of the evolution of the horse. You must understand that every one of these forms has undoubtedly become modified into various species, and we cannot be absolutely certain that we have found those species which constitute the exact line of modification, but it was perfectly obvious that we had here in succession, in time, three forms of the horse-type, of which the oldest came nearest to the general mammal. We saw that the forms which had existed afterward had undergone a reduction of the number of their toes, a reduction of the fibula, a more complete coalescence of the ulna with the radius. The pattern of the molar teeth had become more complicated and the interspaces of their ridges had become filled with cement. In this succession of forms you have exactly that which the hypothesis of evolution demands. The history corresponds exactly with that which you would construct *a priori* from the principles of evolution. An alternative hypothesis is hardly conceivable, but the only one that could be framed would be this, that the *Anchitherium*, the *Hipparion*, and the horse, had been created separately and at separate epochs of time. For that hypothesis there could be

no scientific evidence, and it is not pretended that there is the slightest evidence of any other kind that such successive creation has ever taken place. When I was investigating this subject only the collections in Europe were accessible to me, but the materials they yielded led me to think that the horse must have descended from an *Anchitherium*-like ancestor, and I may say, as I happen to know by correspondence with him, that very eminent anatomist, the late Prof. Lartet, of Paris, had arrived independently at the same conclusion. Indeed, the story is so plain that no one deserves any particular credit for drawing so obvious a conclusion. And since then paleontological inquiry has not only given us greater and greater knowledge of the series of horse-like forms, but enabled us to fill up the gaps in the series, and to extend that series farther back in time.

That knowledge has recently come to us, and assuredly from a most unexpected quarter. You are all aware that when this country was first discovered by Europeans there were no traces of the existence of the horse in any part of the American Continent. And, as is well known, the accounts of the earlier discoveries dwell upon the astonishment of the natives when they first became acquainted with that astounding phenomenon—a man seated upon a horse. Nevertheless, as soon as geology began to be pursued in this country, it was found that remains of horses—horses like our European horses—like the horses which exist at the present day—are to be found in abundance in the most superficial deposits in this country, just as they are in Europe. For some reason or other—no feasible suggestion on that subject, so far as I know, has been made—but for some reason or other the horse must have died out on this continent at some period preceding—how long we cannot say—the discovery of America by the Europeans. Of late years there have been discovered on this continent—in your Western Territories—that marvelous thickness of tertiary deposits to which I referred the other evening, which gives us a thickness and a consecutive order of older tertiary rocks admirably calculated for the preservation of organic remains, such as we had hitherto no conception of in Europe. They have yielded fossils in a state of preservation and in number perfectly unexampled. And with respect to the horse, the researches of Leidy and others have shown that numerous forms of that type are to be found among these remains. But it is only recently that the very admirably contrived and most thoroughly and patiently worked-out investigations of Prof. Marsh have given us a just idea of the enormous wealth and scientific importance of these deposits. I have had the advantage of glancing over his collections at New Haven, and I can truly and emphatically say that, so far as my knowledge extends, there is nothing in any way comparable, for extent, or for the care with which the remains have been got together, or for their scientific importance, to the series of fossils which he has brought together. (Applause.) This enormous

collection has yielded evidence of the most striking character in regard to this question of the pedigree of the horse. Indeed, the evidence which Prof. Marsh has collected tends to show that you have in America the true original seat of the equine type—the country in which the evidence of the primitive form and successive modifications of the horse series is far better preserved than in Europe; and Prof. Marsh's kindness has enabled me to put before you the following diagram, every figure in which is an actual representation of the specimen which is preserved in New Haven at this present time. The succession of forms which he has brought together shows, in the first place, the great care and patience to which I have referred. Secondly, there is this Pliocene form of the horse (*Pliohippus*); the conformation of its limbs presents some very slight deviations from the ordinary horse, and with shorter crown of the grinding teeth. Then comes the form which represents the European *Hipparion*, which is the *Protohippus*, having three toes and the forearm and leg and teeth to which I have referred, and which is more valuable than the European *Hipparion* for this reason: it is devoid of some of the peculiarities of that form—peculiarities which tend to show that the European *Hipparion* is rather a side branch than one in the direct line of succession. Next comes the *Miohippus*, which corresponds pretty nearly with what I spoke of as the *Anchitherium* of Europe, but which has some interesting peculiarities. It presents three toes—one large median and two lateral ones; of the toe which answers to the little finger of the human hand, there is only a rudiment. This is, however, as far as European deposits have been enabled to carry us with any degree of certainty in the history of the horse. In the American tertiaries, on the contrary, the series of equine forms is continued down to the bottom of the Eocene. The older Miocene form, termed *Mesohippus*, has three toes in front and a large splint-like rudiment representing the little finger, and three toes behind. The radius and ulna are entire, and the tibia and fibula distinct, and the teeth are anchitheroid with short crowns.

But the most important discovery of all is the *Orohippus*—which comes from the lower part of the Eocene formation, and is the oldest member of the equine series known. Here we have four complete toes on the front-limb, three toes on the hind-limb, a well-developed ulna, a well-developed fibula, and the teeth of simple pattern. So you are able, thanks to these great researches, to show that, so far as present knowledge extends, the history of the horse-type is exactly and precisely that which could have been predicted from a knowledge of the principles of evolution. And the knowledge we now possess justifies us completely in the anticipation that when the still lower Eocene deposits and those which belong to the Cretaceous epoch have yielded up their remains of equine animals, we shall find first an equine creature with four complete toes and a rudiment of the innermost toe in front, and probably a rudiment of the fifth toe in the


Fore Foot.
Hind Foot.
Fore-arm.
Leg.
Upper Molar.
Lower Molar.
RECENT.
EQUUS.
PLIOCENE.
PLIOHIPPUS.
PROTOHIPPUS
(*Hipparion*).
MIOCENE.
MIOHIPPUS
(*Anchitherium*).
MESOHIPPUS.
EOCENE.
OROHIPPUS.

hind-foot.[1] In still older forms the series of the digits will be more and more complete, until we come to the five-toed animals, in which most assuredly the whole series took its origin.

That is what I mean, ladies and gentlemen, by demonstrative evidence of evolution. An inductive hypothesis is said to be demonstrated when the facts are shown to be in entire accordance with it. If that is not scientific proof, there are no inductive conclusions which can be said to be scientific. And the doctrine of evolution at the present time rests upon exactly as secure a foundation as the Copernican theory of the motions of the heavenly bodies. Its basis is precisely of the same character—the coincidence of the observed facts with theoretical requirements. As I mentioned just now, the only way of escape, if it be a way of escape, from the conclusions which I have just indicated, is the supposition that all these different forms have been created separately at separate epochs of time, and I repeat that of such an hypothesis as this there neither is nor can be any scientific evidence, and assuredly, so far as I know, there is none which is supported, or pretends to be supported, by evidence or authority of any other kind. I can but think that the time will come when such suggestions as these, such obvious attempts to escape the force of demonstration, will be put upon the same footing as the supposition made by some writers, who are, I believe, not completely extinct at present, that fossils are not real existences, are no indications of the existence of the animals to which they seem to belong; but that they are either sports of Nature or special creations, intended—as I heard suggested the other day—to test our faith. In fact, the whole evidence is in favor of evolution, and there is none against it. And I say this, although perfectly well aware of the seeming difficulties which have been adduced from what appears to the uninformed to be a scientific foundation. I meet constantly with the argument that this doctrine of evolution cannot be correct, because it requires the lapse of a very vast period of time, and that the duration of life upon the earth thus implied is inconsistent with the conclusions arrived at by the astronomer and the physicist. I may venture to say that I am familiar with those conclusions, inasmuch as some years ago, when President of the Geological Society of London, I took the liberty of criticising them, and of showing in what respects, as it appeared to me, they lacked complete and thorough demonstration. But, putting that point aside altogether, suppose that, as the astronomers, or some of them, and some physical philosophers, tell us, it is impossible that life could have endured upon the earth for as long a period as is required by the doctrine of evolution—supposing that to be proved, what I want to know is, what is the foundation for the statement that

[1] Since this lecture was delivered, Prof. Marsh has discovered in the lowest Eocene deposits of the West a new genus of equine mammals (*Eohippus*), which corresponds very nearly to this description.—*American Journal of Science*, November, 1876.

evolution does require so great a time? The biologist knows nothing whatever of the amount of time which may be required for the process of evolution. It is a matter of fact that those forms which I have described to you occur in the order which I have described in the tertiary formation. But I have not the slightest means of guessing whether it took a million of years, or ten millions, or a hundred millions, or a thousand millions of years, to give rise to that series of changes. As a matter of fact, the biologist has no means of arriving at any conclusion as to the amount of time which may be needed for a certain quantity of organic change. He takes his facts as to time from the geologist. The geologist, taking into consideration the rate at which deposits are formed and the rate at which denudation goes on upon the surface of the earth, arrives at certain more or less justifiable conclusions as to the time which is required for the deposit of a certain amount of rocks, and if he tells me that the tertiary formations required 500,000,000 years for their deposit, I suppose he has good ground for what he says, and I take that as the measure of the duration of the evolution of the horse from the *Orohippus* up to its present condition. And, if he is right, undoubtedly evolution is a very slow process, and requires a great deal of time. But suppose, now, that an astronomer or a physicist—for instance, my friend Sir William Thomson—comes to me and tells me that my geological friend is quite wrong, and that he has capital evidence to show that life could not possibly have existed upon the surface of the earth 500,000,000 of years ago, because the earth would have been too hot to allow of life, my reply is: "That is not my affair; settle that with the geologist, and when you have come to an agreement between yourselves I will adopt your conclusion." We take our time from the geologist, and it is monstrous that, having taken our time from the physical philosopher's clock, the physical philosopher should turn round upon us, and say we are going too fast. What we desire to prove is, is it a fact that evolution took place? As to the amount of time it took, we are in the hands of the physicist and the astronomer, whose business it is to deal with those questions.

I think, ladies and gentlemen, that I have now arrived at the conclusion of the task which I set before myself when I undertook to deliver these lectures before you. My purpose has been, not to enable those of you who have not paid attention to these subjects before to leave this room in a condition to decide upon the validity or the invalidity of the hypothesis of evolution, but to put before you the principles by which all such hypotheses must be judged; and, furthermore, to make apparent to you the nature of the evidence and the sort of cogency which is to be expected and may be obtained from it. To this end I have not hesitated to regard you as genuine students and persons desirous of knowing the truth. I have not hesitated to take you through arguments, even long chains of arguments, that I

fear may have sometimes tried your patience, or to have inflicted upon you details which could not possibly be escaped, but which may well have been wearisome. But I shall rejoice—I shall consider I have done you the greatest service which it was in my power in such a way to do—if I have thus convinced you that this great question which we are discussing is not one to be dealt with by rhetorical flourishes or by loose and superficial talk, but that it requires the keenest attention of the trained intellect and the patience of the most accurate observer. When I commenced this series of lectures, I did not think it necessary to preface them with a prologue, such as might be expected from a stranger and a foreigner; for, during my brief stay in your country, I have found it very hard to believe that a stranger could be possessed of so many friends, and almost harder to imagine that a foreigner could express himself in your language in such a way as, to all appearances, to be so readily intelligible; for, so far as I can judge, that most intelligent, and, perhaps, I may add most singularly active and enterprising body, your press reporters, do not seem to have been deterred by my accent from giving the fullest account of everything that I happen to have said. But the vessel in which I take my departure to-morrow morning is even now ready to slip her moorings; I awake from my delusion that I am other than a stranger and a foreigner. I am ready to go back to my place and country, but, before doing so, let me, by way of epilogue, tender to you my most hearty thanks for the kind and cordial reception which you have accorded to me; and let me thank you still more for that which is the greatest compliment which can be afforded to any person in my position—the continuous and undisturbed attention which you have bestowed upon the long argument which I have had the honor to lay before you.

THE STUDY AND TEACHING OF BIOLOGY.[1]

By Professor H. NEWELL MARTIN, D. Sc., M. B., B. A.

WE meet to-morrow to formally begin the biological work of this University—to commence that systematic study of animal and vegetable form and function, relationship and distribution, which we include under the names of Comparative Anatomy, Zoölogy, Physiology and Botany, or in the general terms Biology or Natural History. I have thought that it might be well to-day to take an opportunity of laying before you what seem to be the ends which we should hold in view, and the methods on which we should work, if we are to attain or to deserve a permanent success. I am further induced

[1] An introductory lecture delivered at the Johns Hopkins University, October 23, 1876.

to take this course by the fact that our present year's work is confessedly of a tentative nature: one main object of it being to enable us to decide upon what lines we are to go forward in the future; and I believe it may facilitate decision on some points if we have before us, as a sort of basis for discussion, a definite statement of views on the subject, no matter how imperfect such statement may be in itself, or how much the opinions expressed in it may afterward be found to require modification. What I propose, therefore, is not simply to tell you what are our arrangements for this year, but also to put before you some thoughts as to what I think we ought to do in the time to come. It is, I am sure, unnecessary for me to dilate at any length, before this audience, upon the interest and importance of biological studies. However contributory to our culture and welfare other studies may be, biology has, and ever must have, a very special interest of its own: it alone deals with the living organisms which surround us, and which are the only things that share with us that wonderful collocation and interaction of natural forces which we call *life*. Biology, too, includes within its range the study of man himself, so far as one side of his nature is concerned; and, as regards his mental and moral qualities, the psychologist and sociologist have already begun to recognize that the progress of their sciences is closely bound up with the development of certain branches of biology. As regards its practical value I might set forth at length the indebtedness of scientific medicine and of sanitary science to biology; but I prefer not to recommend the study to you by such considerations. This is a university: and the object of a university, I take it, is directly to promote liberality of thought and culture, and only indirectly to concern itself with the practical advancement of material welfare. It is concerned rather with the acquirement of a knowledge of principles than with their practical applications; although, in connection with it, it may have subsidiary schools where those who have already learned the principles may acquire a practical knowledge of various arts. Nevertheless it is true that, if we devote ourselves to the higher objects, the rest will be added unto us; for it is one of the great glories of all the physical sciences that, while second to none in the training which a study of them gives to all the faculties of the mind—in the promotion of large and liberal ideas, and in the gratification of that longing to "know," which is the noblest characteristic of the human intellect—they at the same time, as a by-thing, but constantly, contribute to the increase of man's comfort, and to the material prosperity and happiness of his race. Those who advance our knowledge of the laws of animal and vegetable life may work without any immediate outlook to the advancement of medicine, hygiene, and agriculture, but such advancement constantly follows and springs from their work, and will ever do so.

To those who are in any degree acquainted with the state

of the scientific world, the present must seem a specially opportune time for founding a biological school. At no previous period has such an interest been taken in biological problems, or have so many earnest workers been in the field—never before has so rich a harvest been in view. This is mainly owing to the promulgation of two great ideas within the last few years. On the morphological side we have the doctrine of evolution applied to living forms, and especially as definitely put forward by the theory of the origin of species by natural selection; while on the physiological side we have the doctrine of the conservation of energy, and its extension to the play of forces in living organisms. It matters not whether these theories be correct representations of the facts or not, or whether increase of knowledge confirms or upsets them—in any case they have been of incalculable importance in stimulating work and in giving a present and direct significance to its results. I can imagine no time for the biologist to live in which would be more interesting than the coming half-century, or none in which he will have a greater incentive to study; he seems to have almost within his grasp the solution of problems of the widest significance.

Those of us directly concerned in the administration of the biological laboratory here, are charged with the fulfillment of two duties: we have to make provision for the advancement of knowledge, and for its diffusion; we are to find accommodation and assistance for both investigators and students; while we must not suffer those engaged in research to be crowded out by beginners, neither must the beginners be overlooked in providing for those to whom they are one day to succeed. The liberal space at our disposal will permit us, at any rate for the present, to accommodate both classes of workers, without risk of the extermination of either. Meanwhile I have, then, to occupy your time with a few words on two subjects: on biological research, and on biological teaching.

One hears a good deal talked nowadays of scientific research, and among it a good deal of what I cannot but think mischievous nonsense about the peculiar powers required by scientific investigators. To listen to many, one would suppose that the faculty of adding anything whatever to natural knowledge was one possessed by extremely few persons. I believe, on the contrary, that any man possessed of average ability and somewhat more than average perseverance, is capable, if he will, of doing good original scientific work. Any hard-working and commonly intelligent man, who likes his profession, will make a good soldier, or lawyer, or doctor, though that combination of powers which makes the great general, or the great jurist, or the great physician, is given to but few.

So it is with the pursuit of Science: assuredly not every one of her followers, very probably not one among us now present, will be-

come a Linnæus, or a Cuvier, or an Agassiz. It may not be given to any of us to make some brilliant discovery, or to first expound some illuminating generalization; but we can, each and all, if we will, do good and valuable work in elucidating the details of various branches of knowledge. All that is needed for such work, besides some leisure, intelligence, and common-sense (and the more of each the better), is undaunted perseverance and absolute truthfulness; a perseverance unabated by failure after failure, and a truthfulness incapable of the least perversion (either by way of omission or commission) in the description of an observation or of an experiment, or of the least reluctance to acknowledge an error once it is found to have been made. Moreover, this love of truth must extend to a constant searching and inquisition of the mind, with the perpetual endeavor to keep inferences from observation or experiment unbiased, so far as may be, by natural predilections or favorite theories. Perfect success in such an endeavor is, perhaps, unattainable, but the scientific worker must ever strive after it; theories are necessary to guide and systematize his work, and to lead to its prosecution in new directions, but they must be servants, and not masters. I may, perhaps, seem to be insisting at too great length on a self-evident point; but the more one knows of scientific work and workers, the more does one realize the importance and the difficulty of attaining a perfectly-balanced mind and of arriving at an unprejudiced deduction from observation.

I believe, then, that the only absolutely necessary faculties for the scientific investigator are love of his work, perseverance, and truthfulness; to make the great leader and master in science, one of those who cast a new ray of light on our conceptions of the universe, other and far rarer powers are, of course, needed—the most essential being originality of thought; and, as that cannot be either self-taught or taught from outside but must be born in the bone, all that the rest of us can do when we meet such men is to give them a free course and ungrudging help. That an army may attain its best success, needs indeed that every man be brave and loyal, but it is by no means requisite that every soldier be a brigadier-general; so in the army of Science there is place for soldiers of all ranks and capabilities—and, at any rate, we know this, that Nature reveals her secrets, which are her rewards, on no system of purchase or favoritism—what a man deserves that he gets, every drummer-boy who enters her service carries the marshal's *bâton* in his pocket. His reward will be proportionate to the amount of time and intelligence he devotes to his work; given, in addition, certain opportunities which every one has not for himself, but which it is one great object of such institutions as this to provide for all.

If what I have just stated be the general requisites of the scientific investigator, we have next to inquire what special needs has the biologist: these may all be grouped under the head of preliminary train-

ing. He must have a fair knowledge of mechanics, experimental physics, and chemistry; he ought to (I would almost again say he *must*) be able, besides English, to read at least French and German with facility—assuredly, if he cannot, he will labor with much toil and sorrow—and the more mathematics he knows, with the present rapid importation of quantitative ideas into biological science, the better for him; and for certain special branches of biological work there are other special needs. No mistake is more disastrous than the idea that a man can be a botanist and nothing more; a zoölogist, and nothing more; a physiologist, and nothing more. It is true that no one can be master of all the physical sciences, but it is none the less true that hardly one of them can be entirely neglected by the biologist. Animals and plants are, after all, material objects, and live in accordance with the laws that govern matter; but the manifestations of these laws are so often obscured and complicated by the conditions in which they occur in living things, that the understanding of them is only to be got at by approaching them through their simpler manifestations in inorganic bodies. But, apart from that, definite knowledge of various sciences is constantly required by the biologist. How can one ignorant of physics have any real appreciation of the statement that the transmission of a nervous impulse is accompanied by a molecular alteration in the structure of a nerve-fibre, one sign of which is a certain very definite and peculiar alteration in its electrical properties; or how can one ignorant of chemistry grasp the fundamental statement that muscular work is in the long-run dependent on the breaking down of complex chemical molecules into simpler and more stable ones? How can the zoölogist or botanist scientifically study the distribution of animals and plants in space, unless he has a knowledge of physical geography; or in time, unless he knows something of geology? I need not prolong the list.

Furthermore, no one can properly study any branch of biology without some knowledge of its other divisions. The fundamental laws of animal and vegetable life are identical, and only fully realized by comparison; so, while the scientific botanist, to fully appreciate the facts of his own science, must be something of a zoölogist, so must the zoölogist know something of plants: no one living being or group of living beings can be properly understood by itself. To take other examples: how is the morphologist to deal with such problems as those presented to him by rudimentary organs, unless he know something of the functions of parts, which is the special domain of physiology; or, how is he to understand the influence of external conditions in the production and preservation of variations in force, without, again, this knowledge of function? And, as regards the physiologist, he has frequently to search the whole animal and vegetable kingdoms not only to discover those forms which give him the best opportunity of studying certain phenomena, but also to get at those

fundamental ideas which lie at the base of his whole science. What general and broad ideas should we have of the contractility of protoplasm if we only knew it in the highly-specialized form of a muscular contraction; or of its irritability, if we only knew it as exhibited in the nervous apparatus of one of the higher animals? It is quite true that, without any breadth of knowledge, a man may collect, label, and store away thousands of plants; he may macerate and articulate the most beautiful skeletons; he may cut, stain, and mount, the most exquisite microscopic preparations: but assuredly he is not likely to do any work entitled to the name scientific; such mechanical work has its value, no doubt, but it is only preliminary to real scientific work—which latter requires wide knowledge and extended views, and is more valuable the broader the foundation on which it has been built up.

It is this mutual dependence of biological studies which appears to me the justification of grouping together, as we do here, the study of such a number of vast subjects in a single laboratory. By that means each investigator will receive knowledge and assistance from the other; under such a system the desirable intercommunication of ideas is rendered most easy; and we are most likely to escape that narrow specialism which every laboratory in the long-run has a tendency to get into. Of course, no one person is capable of giving detailed assistance in investigations in all the branches of biology; but our staff of professors will doubtless grow, and meantime we shall, I trust, by the associate and fellowship system of the university, have at all times among us well-qualified men in every branch of biology; so that no one fitted for the task, and earnest and willing in its prosecution, who may come here to undertake any special research, will fail to find some one able and willing to advise him when he needs advice, and to assist him when he needs assistance.

What we want here, then, is men with the requisite zeal and training for investigation—we care not whether classification, or morphology, or physiology, or any other branch of biology is their specialty; all we claim is that they shall be able to work, shall mean to work, and shall work—we shall give no quarter to the indolent or ignorant: the former we will not have on any terms, and the latter must enter for the preparatory courses, and will not be allowed to occupy tables set apart for research. Surely, if we select wisely, and find men to work faithfully, we may look forward with confidence to the time when we shall find ourselves in the condition of such laboratories as those of some of the German universities, where, on account of the high class of work done in them, the ablest young men from all over the world beg for admission; where one finds, working side by side, men from every civilized nation, and where, in the presence of the great demand for admission, entry is esteemed a precious privilege.

As to the special aid which we can offer to those who come among us to engage in investigation, it will, of course, depend on two factors,

upon the natural gifts of those charged with the supervision of the laboratory, and the amount of money which those whose duty it is to decide on such matters see right to place at their disposal: for, however important we biologists may think ourselves, the fact remains that there are other studies to be provided for, and studies just as important as our own. For the present I can say, however, that we have at our disposal one large and well-lighted room for general work—a room fitted up for physiologico-chemical investigations—and several smaller rooms for physiological and histological research. As regards instruments we have ordered, and in part received, a very excellent stock, including the most essential ones for every branch of physiological research—and I have no doubt that every year we shall receive grants to add to our stock, and keep up with the times.

The zoölogical and comparative anatomy departments differ from the physiological in not needing so many special instruments; what they mainly need are (besides work-rooms) material for examination and dissection, and books, especially monographs, and those we shall make it a point, to the best of our power, to obtain from time to time as they are wanted. It seems to me that it is not our duty to provide vast herbaria and museums containing every plant and animal under the sun—to provide such collections is the duty rather of the nation than of a university—nor do I think we should be wise to collect and store away things promiscuously, in the hope that some one will want them some time. We should rather concentrate our force on getting what is wanted for the time being. If some one wants to elucidate any point in the structure of the Echinoderms, for example, we should do our best to obtain specimens for him—even from all parts of the world; if some one else wants to work at the embryology of any fish or amphibian, we should again endeavor to get him the eggs in various stages of development, and so on; but I doubt the wisdom of sending out collectors with orders to store away everything they can catch, fish, flesh, and fowl, in spirit, and send it to us. We have nowhere to display such collections if we got them—the vastly greater part of them would never be used—and when reference to extensive collections is necessary, we have always at hand the admirable museum illustrating the fauna and flora of this State which is being brought together by the Academy of Sciences in this city, and the national collections at Washington are within an hour's journey of us. Bringing together from time to time such materials for special researches as I have indicated above, will naturally entail considerable expenditure, but I am sure that the trustees, if they see we mean work, will do all they can to supply our needs.

Now let us turn to the other part of our subject, biological teaching: from part of what I have already said you have doubtless gathered something of my views on this matter. If biology be the complicated study that I have endeavored to indicate, it is in the first

place clear that, in justice both to the student and his teachers, a certain preliminary training must be insisted upon as a preparation for his admission to a biological laboratory; at least the student must have a fair knowledge of physics and chemistry before he comes there; and, when he gets there, the thing next to insist upon is, that his teaching be as largely demonstrative and practical as possible, lectures being made of secondary and laboratory-work of primary importance.

It matters not to me where the student gets this preparatory knowledge; whether here or at some other institution. I believe he ought to acquire it largely at school, as a part of general education; but, as that seems in the present condition of primary education almost impossible, I shall perhaps best make clear my ideas on the matter if I endeavor to sketch out what I think should be the course gone through by a youth fresh from some high-school or college, where he has got an otherwise sound general education, but without anything more than a sham knowledge of physics, and who enters this university with the intention of qualifying himself for biological research or teaching hereafter; and you will, I hope, forgive me if, with the same object of obtaining clearness, I put what I have to say into a somewhat dogmatic form.

Such a person ought to enter at once upon courses of instruction in experimental physics and chemistry, and devote almost wholly his first year to them; but during the latter part of that year, say between the spring vacation and the end of the session, he would, in addition, go through a course of instruction in what we may call general biology. By that I mean a course of instruction in which he would acquire some knowledge of how to use his microscope and how to dissect, and thus gain a certain amount of that special manipulative dexterity which he will require afterward. He would also gain a general acquaintance with biological ideas, and with the meaning of the more important technical terms: he would gain, for example, a real, because a practical, knowledge of what we mean by classification, and of the principles on which classifications are founded; he would learn similarly, with his eyes as well as his ears, what we mean by morphology, and homology, and a host of similar terms; and he would, in addition, acquire a special acquaintance with the structure and actions of certain selected typical animal and vegetable forms. This, then, would finish the first year's work, unless our student should be ignorant of French and German. If so, he ought also to acquire, what is really very easily got, at least a fair reading knowledge of those languages.

At the commencement of his second year the student should enter for two elementary practical courses, one on comparative anatomy and zoölogy, the other on animal physiology. These courses would, I imagine, last about six months each, and they should be taken *pari*

passu. Each would consist, say, of two lectures a week, and the rest of the time would be filled up with the dissection of typical animals, the performance of the simpler physiological experiments, and the preparation and examination of microscopic specimens of animal tissues, all illustrative of the main points put forward in the lectures. The student would also be made to draw sketches of his dissections and microscopic preparations, and to describe them and the results of his experiments briefly in writing, and so while learning thoroughly how to dissect and use his microscope, and the conditions of success in physiological experiment, he would also have his powers of observation regularly trained and tested.

In connection with these courses there should be a museum, containing not a bewildering multitude of specimens, but a small number of dissections and skeletons of typical animals, especially of those which it is important for the student to know, but which are too rare to be obtained in quantities allowing each to dissect one for himself; and these specimens should be so placed that they may be freely accessible to those desiring to study them. It is far better to have to replace an injured specimen occasionally than to have the things locked up behind glass doors, so as to render their thorough examination impracticable to those for whose examination they are placed there. Moreover, especially in connection with the physiological course, there would be needed from time to time, according to the subject-matter of the lectures, demonstrations of certain points; in cases, for instance, needing the employment of the more delicate instruments, or where niceties of manipulation were required, such as a beginner could not be fairly expected to overcome.

I ought perhaps here to refer to the subject of vivisection. Physiology is concerned with the phenomena going on in living things, and vital processes cannot be observed in dead bodies; and from what I have said you will have gathered that I intend to employ vivisections in teaching. I want, however, to say, once for all, that here, for teaching purposes, no painful experiment will be performed. Fortunately, the vast majority of physiological experiments can nowadays be performed without the infliction of pain, either by the administration of some of the many anæsthetics known, or by previous removal of parts of the central nervous system; and such experiments alone will be used here for teaching. With regard to physiological research the case is different: happily here too the number of necessarily painful experiments is very small indeed; but in any case where the furtherance of physiological knowledge is at stake—where the progress of that science is concerned, on which all medicine is based, so far as it is not a mere empiricism—I cannot doubt that we have a right to inflict suffering upon the lower animals, always provided that it be reduced to the minimum possible, and that none but competent persons be allowed to undertake such experiments. Placed,

moreover, as we shall be here, in more or less close connection with a splendidly-equipped hospital, so that we shall be able constantly to combine skilled pathological observation with physiological experiment in an excellent laboratory, we have duties to perform toward the advancement of scientific medicine, from whose performance I believe it would be criminal in us, as it would be shameful, to flinch in any way.

But to return to our special subject: the last three months of the student's second year should be occupied with a laboratory course of instruction in vegetable morphology and physiology, and with a course of lectures on embryology, accompanied with a full practical study of the development of the chick from the earliest stages of incubation.

The student will have now got an extensive acquaintance with biological facts and methods, and henceforth he should be allowed and encouraged to specialize his work. He would be permitted to select for more detailed study in his third year either animal morphology, or botany, or physiology, and the best men in each subject would be picked out and allowed to act as demonstrators to the second-year students, and so be given the opportunity of acquiring a far more accurate knowledge than they could attain in any other way. For these third-year men, too, short advanced courses of lectures would be given from time to time, such as on the physiology of nutrition, the physiology of the senses, the geographical distribution of animals, on special morphological points, and so on, and also on the more important recent discoveries in various branches; and the best of them might be put on some easy bit of original work, to try their metal and whet their appetites.

After all this has been gone through, I think we can do no more in the way of teaching for our typical student; he has now advanced enough to teach himself, and, if he is good for anything, will do it better than others can do it for him. I think that among students so taught, as I have endeavored to indicate, we should be certain to meet with a large number of well-qualified men from among whom to select some of our fellows and associates, and would be justified in expecting from them work of the highest quality. As regards the remainder, those who display no special aptitude for scientific investigation, or no desire to devote themselves to science as a profession, they will at least have had the opportunity of acquiring a very thorough and practical knowledge of what modern biology means.

It now remains for me to give a sketch of what our work for the present year will be, so far as I see my way at present. To-morrow I commence a course of lectures on animal physiology, which I propose to deliver twice a week, on Tuesdays and Fridays, at 1.15 P. M. I have been induced to select this hour on account of special circumstances affecting many of those who wish to attend this year, though as

a general rule I should like an earlier hour, nine or ten in the morning, which definitely brings a man early in the day to the laboratory, and gives me a better chance of getting a good day's work out of him. These lectures will be designed rather for those who have already some knowledge of physiology than for beginners; for so many instruments have not yet arrived, and so many arrangements are necessarily as yet imperfect, that it seems better for the present only to invite men who are more or less fitted by previous training to overcome such occasional difficulties and inconveniences as may from time to time arise from such causes. When I say that the lectures will be rather adapted for advanced students than beginners, I do not mean, however, that I shall omit elementary but important facts, but that, in addition to those, I shall from time to time discuss at more or less length points which are still *sub judice*. The lectures will be illustrated by no experiments: partly because, on account of the rapid changes which go on in living tissues, physiological-lecture experiments are likely to be the reverse of successful (a frog's muscle which has been lying on the table since the commencement of a lecture is very apt to contract abnormally when the lecturer wants it); but mainly because I want each student to make the illustrative observations and experiments for himself—except in cases of unusual difficulty, when demonstrations will be given at such hours as may be found most convenient to the majority. In the lectures I shall presuppose the possession by each present of such a knowledge of anatomy as is necessary for physiological work, and, starting with the structure of blood, go regularly on through the histology and physiology of the tissues and organs of the animal body. These lectures will continue until the spring vacation, and then I mean to set to work specially for more elementary students, and put them through such a course of general biology as I have already described; but possibly either Dr. Brooks or myself will give at that time some instruction in embryology of a more advanced character.

As regards physiological research, several gentlemen have already consulted me with reference to undertaking investigations in different directions, and of course there is plenty of work to be done should others qualified for it present themselves. One difficulty which I have met with is that many seem to consider that a physiological investigation can be carried on by devoting to it an hour or two at irregular intervals: I feel quite sure that no good work is likely to be done in that way, and am not inclined to encourage such workers. Some, at least, of those engaged in investigation will be able to have accommodation in the special rooms, apart from the general laboratory, which have been provided for that purpose.

On the zoölogical and morphological side no arrangements have as yet been made for a lecture and laboratory course this year, nor so far as I know has any such demand as would render it advisable

shown itself. Should it do so, however, we may, perhaps, make arrangements for elementary instruction in those subjects, under the more immediate superintendence of Dr. Brooks, our associate in biology, upon whose shoulders I must throw most of the burden of that side of the work. We shall, at any rate, collect material and make other preparations for such a course next year. After Christmas Dr. Brooks will give a course of lectures on "Morphological Theories."

For the present, too, we shall have in the laboratory several well-trained zoölogists and morphologists; some engaged in prosecuting advanced studies, others in research. I fancy all of them are (as they ought to be) pretty well qualified to take care of themselves; but Dr. Brooks and myself will do our best to give them such assistance as they may need, and to make arrangements by which they can be supplied with such material as they require.

In conclusion, let me say a word to those of you here present who are to be the first workers with me in this laboratory. It behooves you as well as me to recognize what a heavy responsibility lies upon us. Upon the work that we do and the spirit in which we do it, upon the character we give our laboratory at its start, much of its future success or failure depends. If we all work honestly and thoroughly, it will win esteem and reputation; if we are careless and half-hearted, it will become of low repute. Let us, then, each work loyally, earnestly, truthfully, so that when the time comes, as it will come sooner or later, in one way or another, to each of us, to depart hence, we may carry with us a good conscience, and be able to say that in our time no slipshod piece of work ever left the laboratory; that no error we knew of was persisted in; that our only desire was to know the truth. Let us leave a record which, if it perchance contain the history of no great feat in the memory of which our successors will glory, will at least contain not one jot or one tittle of which they can be ashamed.

THE PARALLEL ROADS OF GLEN ROY.

FROM a lecture recently delivered by Prof. Tyndall before the Royal Institution, we gather the following facts in regard to that natural wonder in Scotland, which for so long remained a puzzle to all investigators. There is an unusual interest centred around its history, from the time when the country-people explained it by their crude and half-mythical theories, to the time when it became a labor of love for the untiring efforts and acute observations of scientists.

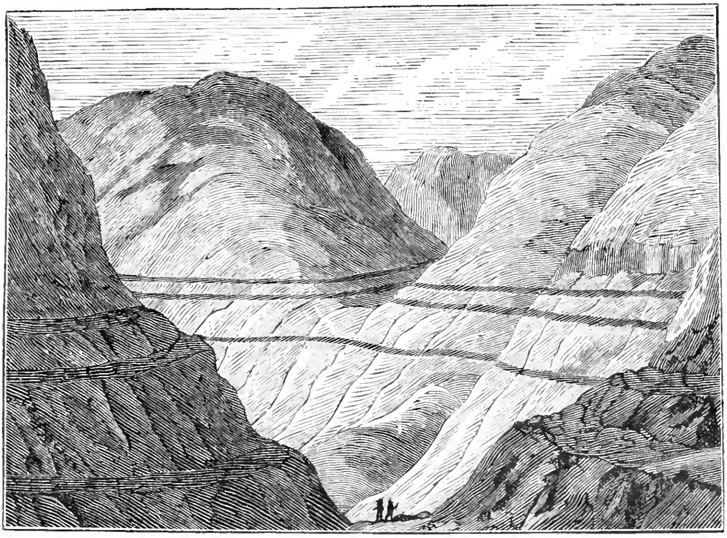
The earliest published allusion to these roads was made in a work brought before the public a century ago, but no systematic description of them appeared before 1817. They are found in the district of

Lochaber, Inverness-shire. On both sides of the steep, narrow glen through which the Roy runs, there are three perfectly horizontal and parallel roads, directly opposite on each side, those on one side corresponding exactly in elevation to those on the other. They are respectively 1,150, 1,070, and 860 feet above the sea, and are formed as shelves in the yielding drift which covers the sides of the mountains. They usually slope somewhat from the hill, and vary in width from one to twenty yards. The two highest stop abruptly at different points near the mouth of Glen Roy, although no barrier now remains to show any reason for it. At some points the grass on the shelves differs from that which is above and below, and, as the roads lie in the midst of heather-covered hills, the absence of the dark shrub from them adds greatly to their conspicuousness.

The terraces were originally supposed to have been made for the heroes whose deeds have been sung by Ossian. A less romantic view was that "they were designed for the chase, and were made after the spots were cleared in lines from wood, in order to tempt the animals into the open paths after they were roused, in order that they might come within the reach of the bowmen who might conceal themselves in the woods above and below." In 1816 Playfair believed them to be aqueducts for artificial irrigation. In 1817 Dr. MacCulloch discussed the probability of there having been lakes embosomed in Glen Roy at one time, and supposed that these roads were the margins of the lakes. It remained, however, for Sir Thomas Dick-Lander to bring forward the facts of the subject, and place them in a scientific light. Adjacent to Glen Roy is Glen Gluoy, along the sides of which there is a single terrace or road, having the same elevation on each side of the valley, and similar in all respects to the roads of Glen Roy. Wishing to see whether these two sides would be united at the head of the glen, and in what manner, he followed them into the mountains. As the valley gradually rose, he observed the shelves approaching each other more nearly; and finally, at the head of Glen Gluoy, he discovered a water-shed of exactly the same elevation as the road which swept around the glen. This height was found to be 1,170 feet, or 20 feet higher than the upper road of Glen Roy. From this water-shed he passed through a lateral branch-valley to Glen Roy, descended to the highest road, and followed it up the glen as he had pursued the previous road. In the same manner he came upon a water-shed looking into Glen Spey, and of precisely the same elevation as the road. After this he dropped down to the lowest shelf, and followed it to the mouth of the glen. It did not end here, however, but doubled around the hills, and ran along the sides of the mountains which flank Glen Spean. Continuing eastward, he observed the Spean Valley gradually approaching the road until the two were on a level, when, as in the other cases, he discovered a water-shed.

From these facts, convinced that water alone could have produced

the terraces, he saw that if the mouth of Glen Gluoy were stopped by a barrier, the waters from the surrounding mountains would be collected in the valley until they had reached the water-shed, when any further rise would be prevented by the branch-valley, which would carry the additional water off to Glen Roy. As long, then, as the barrier remained, there would be a lake in Glen Gluoy, at the exact level of the road, which, by constant action upon the loose drift,



Parallel Roads of Glen Roy.

would be sufficient to produce the road. Now, if the mouth of Glen Roy should also be barred at the same time by a sufficiently high barrier, the waters would be collected behind it, the surface of the lake would rise till it reached the water-shed dividing Glen Roy from Glen Spey, when the superabundant water would flow into the latter valley. In this way the highest shelf of Glen Roy would be formed. If its barrier were now to be partly removed, so as to establish a connection between it and the upper part of Glen Spean, while the lower part remained blocked up, upper Glen Spean and Glen Roy would then be occupied by a continuous lake, the level of which would be determined by the water-shed discovered in Glen Spean. The water in Glen Roy would take a level corresponding to its new place of escape, and the lowest parallel road would be formed. The conclusions thus drawn would be strictly logical, if proof could be offered as to the existence of the barriers.

In Glen Spean there is a large quantity of detritus, and Sir Thomas Dick-Lauder supposed that this had at one time been heaped up by some unknown convulsion. As he could not account for the middle

road of Glen Roy in the same manner, he assumed that at a certain point—the level of this road—the barrier which had been wasting away held its ground for a sufficiently long time to form the road. But, on the same principle, there would naturally have been a greater number of roads in this glen, and additional roads in the other glens. A weakness was thus admitted into the theory which was immediately attacked by Mr. Darwin. He believed that the whole region had once been covered by the sea, and that, in the upheaval of the earth, there were pauses during which these roads were formed. But this would not account for the sea being higher in one of the glens than in another, nor for the unequal number of terraces by which the mountains are belted. As soon as Mr. Darwin detected these fallible points, he abandoned his theory.

In 1847 the Dick-Lander hypothesis received new strength from a discovery made by Mr. Milne-Home. There is a lateral glen, called Glen Glaster, running eastward from Glen Roy, which had escaped the notice of Sir Thomas Dick-Lander. Mr. Milne-Home entered this glen, pursued a branch of it extending to the southeast, and came upon a water-shed exactly level with the second Glen Roy road. On the same theory as before, when the barrier should be properly removed, the water in Glen Roy would sink to the second road, and the surplus water would escape over the Glen Glaster water-shed into Glen Spean. But this mode of explanation could not yet be accepted, for there is scarcely a trace left of the immense quantity of detritus that would have been necessary to form the barriers. Nor could the detritus have been swept away by glaciers, for there have been no glaciers in these valleys since the retreat of the lakes.

At the time when Sir Thomas Dick-Lander was making his investigations, the action of ancient glaciers was not understood. The subject had been pursued in Switzerland, but it was not till 1840 that unmistakable marks of glacier-action were pointed out in Great Britain by Agassiz. He visited Glen Roy, and, having detected the traces of glaciers, pronounced these to have been the barriers blocking up the glens. This theory was afterward examined and confirmed by Mr. Jamieson. "It was their ascription to glacier-action," says Prof. Tyndall, "that first gave the parallel roads of Glen Roy an interest in my eyes; and in 1867, with a view to self-instruction, I made a solitary pilgrimage to the place, and explored pretty thoroughly the roads of the principal glen." At different places he found that the effects of the lapping of the water on the more friable portions of the rock are still perfectly distinct. Several months ago he again visited the place, prior to delivering a lecture upon the subject. The entire ground was thoroughly explored, and the principal hills were found to be intensely glaciated. The collecting-ground of these glaciers, which blocked up the valleys, were the mountains south and west of Glen Spean—among others, Ben Nevis. These lofty mountains en-

counter the southwestern Atlantic winds, and deprive them of their vapor. During the glacial epoch this vapor was precipitated as snow, which slid down the slopes, while every valley and recess kept up a constant supply of glaciers into Glen Spean, filling it to an ever-increasing height. There would of course be ice in Glen Spean, and water to the north of it, as the winds in passing north would be partly dried and warmed by the liberation of their latent heat. As long as the supply was in excess of the consumption, the dams closing the glens would increase in height. As the weather grew warmer, the opposite would be true. For a long time the conflict would continue, retarding indefinitely the disappearance of the barriers, but the ice in the end would have to give way. "The dam at the mouth of Glen Roy, which probably entered the glen sufficiently far to block up Glen Glaster, would gradually retreat. Glen Glaster and its water-shed being opened, the subsidence of the lake 80 feet, from the level of the highest to that of the second parallel road, would follow as a consequence." "In presence, then, of the fact that the barriers which stopped these glens to a height, it may be, of 1,500 feet above the bottom of Glen Spean, have dissolved, and left not a wreck behind; in presence of the fact insisted on by Prof. Geikie, that barriers of detritus would undoubtedly have been able to maintain themselves had they ever been there; in presence of the fact that great glaciers once most certainly filled these valleys—that the whole region, as proved by Mr. Jamieson, is filled with the traces of their action—the theory which ascribes the parallel roads to lakes dammed by barriers of ice has, in my opinion, an amount of probability on its side which amounts to a practical demonstration of its truth."

SCIENCE IN AMERICA.[1]

By Professor JOHN W. DRAPER, M. D., LL. D.

GENTLEMEN, Members and Associates of the American Chemical Society: In accordance with the plan of the American Chemical Society, I am called upon to address you this evening. I have to congratulate you on its successful establishment, and its prospect of permanent success.

Let us consider some of the reasons which would lead us to expect that success, not only for our own, but also for other kindred societies. The field of Nature is ever widening before us, the harvest is becoming more abundant and tempting, the reapers are more numerous. Each year the produce that is garnered exceeds that of the preceding.

[1] Inaugural address before the American Chemical Society, delivered at Chickering Hall, New York, November 16, 1876.

In all directions there is good hope for the future. Perhaps, then, you will listen without impatience for a few minutes this evening to one of the laborers who has taken part in the toil of the generation now finishing its work, who looks back, not without a sentiment of pride, on what that generation has done, who points out to you the duties and rewards that are awaiting you, and welcomes you to your task. Let us look at the prospect before us.

The progress of science among us very largely depends on two elements: fiirst, on our educational establishments; second, on our scientific societies. To each of these I propose to direct your attention; and, first, of our colleges:

Prof. Silliman, in his address delivered on the occasion of the centennial of chemistry, at the grave of Priestley, in commemoration of the discovery of oxygen, makes this remark: "The year 1845 marks the beginning of a new era in the scientific life of America, which is still in active progress, and chemistry has had its full share in this advance." He then enumerates the causes which, in his opinion, had brought about this increased activity. Among them are the centennial celebration of the American Philosophical Society, in Philadelphia, in 1843; the reorganization of the United States Coast Survey, in 1845; the establishment of the Smithsonian Institution at Washington, in 1846; the enlargement of the *American Journal of Science*, in the same year; the contemporaneous foundation of the Astronomical Observatory at Cincinnati; the institution of the Analytical Laboratory at Yale College, in 1847; and, simultaneously, the Lawrence Scientific School at Harvard. To these he adds especially the establishment of the American Association for the Advancement of Science, in 1848. Coinciding with him fully as to the character and power of these and other local causes which he mentions, I cannot but regard them as being themselves the issues of influences of a much more general kind.

A revolution had been taking place in Europe—a revolution not so much political as industrial or social, though it was followed by political consequences of the most important nature. Its commencements may be seen in the preceding century, in the canal-engineering of Brindley; in the improvements of iron-manufacture; in the construction of all kinds of machinery, which reached its acme when the hand of man was deposed from its office, and, through the slide-rest and planing-machine, engines were made by themselves. Then came the exquisite contrivances for the manufacture of textile fabrics, so that a man could do as much work in a day as he had formerly done in a year, the movement in that direction culminating in the two steam-engines, the condenser and non-condenser. The demand for cotton rose; the value of the slave, its cultivator, was enhanced; and the negro question became the paramount political question in the United States. See how scientific discoveries and inventions lead to

political results! Herein, among other great events, we find the origin of the American civil war!

In Europe, the social effect of the use of steam was strikingly marked. Performing mechanical drudgery, it relieved vast numbers of the laboring-class, and gave them time to think. It concentrated them in factories and mills. Those industrial hives were pervaded by literary influences, perhaps not always of a kind that we should approve of. They became the seats of agitation in politics and theology, and, while this was the effect on the laboring mass, the owners or capitalists were accumulating enormous fortunes.

We may excuse the enthusiastic literature of the cotton-manufacture its boasting, for men had accomplished works that were nearly godlike. Mr. Baines, writing in 1833, states that "the length of cotton-yarn spun in one year was nearly five thousand millions of miles—sufficient to pass round the earth's circumference more than two hundred thousand times, sufficient to reach fifty-one times from the earth to the sun. It would encircle the earth's orbit eight and a half times. The wrought fabrics of cotton exported in one year would form a girdle for the globe, passing eleven times round the equator, and more than sufficient to form a continuous sheet from the earth to the moon." And let us not forget that, to give commercial value to this vast result, the capital chemical discovery of bleaching by chlorine was essential. Such was the condition of things in England just previously to the epoch in question. Necessarily, it was followed by great social results.

But there was something more. The locomotive absolutely revolutionized society. A man could now travel farther in an hour than he had previously done in a day. Again, it was clear that important political results were occurring. The effect of the railroad was to render nations more homogeneous, to destroy provincialism. It is actually true that language underwent a change. No one who has remarked the various dialects of the English counties prior to the opening of the Liverpool & Manchester Railway, and the homogeneousness of speech which is fast displacing them, can be blind to this. Simultaneously, a redistribution of the population took place. It was largely withdrawn from the open country, and concentrated in the towns.

In this statement I am recalling facts so common that they are familiar to us all. We all appreciate the immense social changes that took place just before 1845. Who in those times could fail to perceive that grand consequences must follow the expenditure of thousands of millions of dollars in the building of railroads, who, when he saw the labor of a year shrinking into the compass of a day, the travel of a day into the compass of an hour, the thought of man outstripping the velocity of light—who could be so obtuse as not to discern that a new agency had taken possession of the earth, that it

was agitating the nations to their very foundations, that it was ameliorating the lot of man, increasing his power, and dealing remorselessly with old ideas, the fictions and fallacies of the past!

Can we wonder, then, that those who were growing up in the midst of these marvels should not only contrast the activity by which they were surrounded with the stagnation of preceding centuries, but should demand to be made acquainted with the power that was thus opening a new world before their eyes? Very soon it became apparent that there was no provision in the existing educational establishments, the universities and colleges, for this unexpected state of things. These were, to be sure, good enough to initiate a bench of boys into the method of translating an ode of Horace or a few lines of Sophocles, but something more substantial than that was wanted now.

This was the true cause of that influence which began to be felt in America about 1840. Every reflecting person saw that a change in public education was imperative; nay, more was impending. Confronted by the vigor of modern ideas, the system that had come down from the dark ages was seen to have become obsolete.

In addition to these influences, there was another at which we must for a moment glance. Let me, in a few words, sketch its history.

The peninsula of Italy was separated from the rule of the Greek emperors in the eighth century, mainly in consequence of the iconoclastic dispute. Partly through the stress of circumstances, and partly as a matter of policy, the Latin language was brought into such prominence that it was supposed to contain all the useful knowledge in the world. In Western Europe, at the close of the fourteenth century, Greek was totally forgotten.

But when it became clear that Constantinople would be taken by the Turks, many learned men fled to the West, bringing with their language precious classical manuscripts. As it was feared, however, by the dominant authority that knowledge and opinions of an unsuitable kind might thus be introduced, Greek obtained a foothold with much difficulty, and it was only by the aid of Florence, Venice, and other commercial towns of Upper Italy, that after a struggle it made good its ground. The Latin had now a successful rival.

A century later brings us to the culmination of the Reformation. Its literary issue was an admiration of the language of that much-enduring, that immortal race to whom the Old Testament is so largely due. As had been the case with Greek, so now Hebrew passed from a condition of neglect to one of extravagant exaltation. It was believed to have been the original language of the human race, a conviction that proved to be a great stumbling-block to the progress of learning. There were thus three classical languages, each having its own paramount claim.

In 1784 the Royal Asiatic Society was instituted in Bengal. One

of its earliest and most important services was that it brought the Sanskrit language emphatically to the knowledge of Europe. The similarity of this to Latin and Greek, especially in the grammatical forms, struck every one with surprise. At first the old literary party resisted its claims, some of them even affirming that it never had been a spoken tongue, but that it had been fictitiously constructed out of Latin and Greek. The creation of comparative grammar by the great German scholar Bopp, in 1816, threw a flood of light on the subject; and the discovery in 1828, by Hodgson, of the Buddhistic sacred writings in Nepaul, revealed to astonished Europe a literature of grand antiquity and prodigious extent, in which is contained the religious belief of 400,000,000 men—ten times the present population of the United States. Greek and Latin had now to descend from the imperial thrones on which they had been seated, and take their places as later and less perfect forms of this wonderful Oriental tongue.

In the higher regions of literature all over Europe, these discoveries made a profound impression. It was at once seen by the great scholars of the times that the existing educational system, founded, as it so largely was, on the languages of the Mediterranean peninsulas, was altogether on an imperfect basis. They saw that philology was about to occupy a higher platform, and that, though it might cost a struggle with present interests, a change in public education was necessary. But though these languages have suffered an eclipse, there still remains that priceless heritage which they have transmitted to us—immortal examples in national life, in patriotism, in statesmanship, in jurisprudence, in philosophy, in poetry. Still there remain the ruins of the Parthenon, the relics of those statues which have no rival elsewhere in the world—embodiments of the beautiful, before which, even at the risk of being denounced as a pagan, a man might fall down and worship. Still there remains the history of that awful empire which once bore sway around the Mediterranean Sea, an empire to which we owe our civilization, our religious convictions, and even our modes of thought.

I add this great discovery in letters to the scientific and industrial movement I have described as bringing on the epoch of 1840.

Educational institutions are in their nature very much under the influence of the past. They are guided by men of the parting generation, and are essentially conservative. The changes they began to manifest did not originate within them, but were forced upon them from without. They clung to the mediæval as long as they could, and only accepted the modern when they were compelled.

Among American colleges which are emancipating themselves from the mediæval, we may number Columbia, Cornell, Harvard, Princeton, University of Virginia, Yale. Doubtless there are many others that would follow the example if they could, but they are fettered with the gyves of sectarian or local restraint. They march

along, daintily and grotesquely, in the pointed shoes of the fourteenth century.

I linger on this subject of colleges because the example of other countries, and especially of Germany, proves to us that on them our hopes for the development of science must very largely rest. The scientific glory of Germany, not inferior in brilliancy to its military glory, is the creation of its university professors. Among them we find the great chemists and physicists, whose works we study with delight.

Our colleges must separate themselves from the mediæval, and assume thoroughly and sincerely the modern cast. Sincerely, I say, for not a few of them indulge in deception. They would have us believe that they teach physics when they have no modern apparatus; chemistry, when they have no laboratory; botany, without any garden, herbarium, or even drawings; geology, mineralogy, natural history, without any cabinets. So ignorant are some boards of trustees and faculties, that they hold such equipments as luxuries easily dispensed with. I have known some go so far as to affirm that as much money ought to be expended in teaching a few boys Latin and Greek as in giving a demonstrative and illustrated course of science, and even to act on that principle. In institutions under this kind of influence, you will always find that their whole weight is thrown toward the æsthetic. Whatever college honors there may be, whatever emoluments, pass in that direction; and, though through fear of public opinion science cannot be ignored, it is simply tolerated, not cultivated.

From our colleges we may in the second place turn to our scientific societies.

I have referred to the period at which the Greek language became cultivated in Western Europe. The first societies were those established in Florence by its admirers. In the Medicean gardens the lovers of Plato assembled to restore, under an Italian sky, the philosophy that had been extinguished in Athens, and to commemorate by a symposium the birthday of that illustrious man. There is a pleasure in associating with those whose thoughts are congenial to our own, in breathing an atmosphere in which the intellectual makes itself felt.

Very soon the example was imitated. Persons who had a love for science followed the example of those who had a love for letters. The *Academia Secretorum Naturæ* was instituted at Naples in 1560, by Baptista Porta, the inventor of the camera which photographers now so much use; the Lyncean Academy for the Promotion of Natural Philosophy, in 1603; the Royal Society of London, 1645; the Royal Academy of Sciences in Paris, 1666; the Berlin Academy of Arts and Sciences, in 1700. Leibnitz, the rival of Newton, was its first president.

When the Royal Society of London was founded it encountered a bitter opposition. Had it not been for the "merry monarch," Charles II., it must have succumbed beneath the fierce maledictions launched against it.

As in Italy, when the opportunity was offered, men of the same inclination of thinking sought each other, so here, to the surprise of the most enthusiastic chemists, when such an association was proposed, persons seeking membership came crowding in. The society I have the honor of addressing this evening was the result. Already it has completely organized itself; already it has published the first number of its "Proceedings," a publication which I am sure will procure for it approval and respect.

In these organizations of scientific effort, an opportunity of assisting is given to those who, not having dedicated themselves to philosophical pursuits, have yet achieved success in other walks of life, and who, recognizing that the progress of civilization very largely depends on the increase of knowledge, may desire to aid in promoting that great result by the application of their means. See what immense benefits have arisen from the money grants that foreign governments have placed at the disposal of their scientific bodies; see what a stimulus there has been in the award of medals of honor, and, if you desire to witness the effect of a well-judged benefaction, look at the Smithsonian Institution. I would not say one word in disparagement of gifts to colleges and universities, for it is indeed a noble purpose; but endowments for the promotion of a knowledge of Nature conferred on scientific societies for the good of all men, no matter what their country or color, no matter what their religious profession or political condition, are still nobler. The one is a local and transitory benefaction, the other an enduring and universal benevolence.

In our own special science, chemistry, all that has been done has only served to extend the boundary of what remains. The thousands of analyses that have been made have brought us into a wilderness of results. We have not been able to rise to a point of view sufficiently high to discover what is the true place of those results in Nature. We try to represent on the pages of our books and on our black-boards formulas of the constitution of things, conscious all the time that these are at the best only convenient fictions, which must necessarily change as we gain a more perfect insight into that grandest of all problems, the distribution of Force in Space, and the variations to which it is liable. The geometry of chemistry is that of three dimensions, not of two. We have to consider the relation of points not situated on one plane, and hence it is necessary to employ three axes of reference; nay, even more, we cannot avoid the conception of the mathematical method of quaternions. Our inadequate information respecting the real grouping of atoms is followed as a necessary con-

sequence by imperfection in our methods of nomenclature, the confusion in this respect becoming, as we all too well know, every day worse and worse.

And now, while we have accomplished only a most imperfect examination of objects that we find on the earth, see how, on a sudden, through the vista that has been opened by the spectroscope, what a prospect lies beyond us in the heavens! I often look at the bright-yellow ray emitted from the chromosphere of the sun, by that unknown element, Helium, as the astronomers have ventured to call it. It seems trembling with excitement to tell its story, and how many unseen companions it has. And if this be the case with the sun, what shall we say of the magnificent hosts of the stars? May not every one of them have special elements of its own? Is not each a chemical laboratory in itself? Look at the cluster in the sword-handle of Perseus; in Cassiopeia, a universe of stars on a ground of star-dust; in Hercules—of which, as astronomers say, no one can look at for the first time through a great telescope without a shout of wonder—the most superb spectacle that the eye of man can witness! Look at the double stars of which so many are now known, emitting their contrasting rays, garnet, or ruby, or emerald, or sapphire. Each is in accordance with its own special physical conditions, though all are under the same universal ordinance.

Now, here a fact of surpassing importance presses itself on our attention. The movements taking place in those distant bodies are taking place under the same laws that prevail here on earth, and in our solar system. The law of gravitation, as developed by Newton, bears sway in all those distant worlds. In them bodies attract each other with forces directly as their masses and inversely as the squares of their distances. There the laws of the emission, absorption, and transmission of light are the same as they are with us. There ignited hydrogen gives forth its three rays, the same rays that it gives forth to us. In the uttermost parts of the universe the law of definite combination, the numerical law, and the multiple law, stand good. Sodium absorbs its two waves of definite refrangibility, and iron gives in the spectra its more than a hundred lines, more than a hundred silent but convincing witnesses of the uniformity of the constitution of the universe. There the number of vibrations that constitute a ray of definite refrangibility is the same we have found it to be here. In the enormous heat of those central suns the dissociation of molecules may be of a higher order than we can reach artificially, but the law under which it takes place is a continuation of the law here. There, though the weight of a given mass of matter is different from what it is with us, it is nevertheless determined by the law that determines here—the law of gravitation. There energy is indestructible, and is measured as it is measured among us, by work. Then is there any boundary that we can assign to natural law—is it not omnipresent, universal?

Perhaps there is no exaggeration in the assertion—for there seems abundant proof of its truth—that the light by which we see some of those distant orbs has crossed through such a prodigious space that millions of years have transpired during the journey. Then the phenomena it brings to us are those that were engendered in the beginning of the vast time so passed. Whatever there is that is in harmony with facts now happening here, is to us an unimpeachable evidence that the laws which were governing in those old ages have undergone no depreciation, but are active as ever until now. Then shall I exaggerate if I say that those laws are eternal in duration?

Infinite in influence, eternal in duration, what a magnificent spectacle! In the resistless energy of the motions of the universe is there not omnipotence? The Omnipotent, the Infinite, the Eternal, to what do these attributes belong?

Shall a man who stands forth to vindicate the majesty of such laws be blamable in your sight? Rather shall you not with him be overwhelmed with a conception so stupendous? And yet let us not forget that these eternal laws of Nature are only the passing thoughts of God.

But, grand as this is, there is something still grander. There is another temple into which we have to pass, not that of the visible but that of the invisible. We must persist in the invasion we have made, in the revolution we have brought about in physiology. We have to determine the laws which preside in the nervous system of man, and discover the nature of the principle that animates it. Is there not something profoundly impressive in this, that the human mind can look from without upon itself, as one looks at his phantom image in a mirror, and discern its own lineaments and admire its own movements? My own thoughts have of late years been forcibly drawn to this, from a recognition that the interpretation by the mind of impressions from without takes place under mathematical laws, as, for instance, that when external ethereal vibrations create in the mind a certain idea, that same idea will arise when the vibrations are doubled, or tripled, or quadrupled in frequency; but other ideas will be engendered by vibrations of an intermediate rate. Yet what these ideas will be may be predicted. It is true that this is only an optical case, but it extends the view that has been offered to us by a study of the structure of the ear. In the labyrinthine compartment of that organ the ultimate fibres of the auditory nerve are laid on the winding plane of the spiral lamina, in ever-decreasing lengths, each capable of trembling to the sound which is in unison with it—a mechanical action truly, answering to the sympathetic vibration with which the strings of a piano will respond to the corresponding notes of a flute—and these are translated by the mind into all the utterances of articulate speech, all the harmonies of music—speech that engenders new ideas within us, strains which, though they may die away in the air, live

forever in the memory. The exquisite delight we experience in listening to the works of our great composers arises thus in mechanical movements, which are the issue of mathematical combinations. The unseen world is under the influence of number!

But what is number except there be one who numbers? When Pompey, in his Syrian war, broke into the holy of holies at Jerusalem, he expressed, as Tacitus tells us, his astonishment that there was no image of a divinity within; the shrine was silent and empty. And so, though after death we may anatomize and explore the inmost recesses of the brain, the veiled Genius that once presided there has eluded us, and has not left so much as a phantom-trace, a shadow of himself.

The experiments of Galvani and Volta have not yet reached their conclusion; those of Faraday and Du Bois-Reymond have only yielded a preliminary suggestion as to the nervous force. Excepting the great sympathetic nerve, the nervous fibres themselves are, as is well known, of two classes—those that gather the impressions of external things and convey them to the nerve-centres, and those that transmit the dictates of the will from within outwardly. The capabilities of one of the former—the apparatus for sight—have been greatly improved by various optical contrivances, such as microscopes and telescopes, an earnest of what may hereafter be done as respects the four other special organs of sense; and, as concerns the second class, the result of mental operations, the resolves of the will, may be transmitted with greater velocity than even in the living system itself, and that across vast terrestrial distances, or even beneath the sea. Telegraphic wires are, strictly speaking, continuations of the centrifugal nerves, and we are not without reason for believing that it is the same influence which is active in both cases.

In a scientific point of view, such improvements in the capabilities of the organs for receiving external impressions, such extensions to the distances to which the results of intellectual acts and the dictates of the will may be conveyed, constitute a true development, an evolution, none the less real though it may be of an artificial kind. If we reflect carefully on these things, bearing in mind what is now known of the course of development in the animal series, we shall not fail to remark what a singular interest gathers round these artificial developments—artificial they can scarcely be called, since they themselves have arisen interiorly. They are the result of intellectual acts. Man has been developing himself. He, so far as the earth is concerned, is becoming omnipresent. The electrical nerves of society are spread in a plexus all over Europe and America; their commissural strands run under the Atlantic and the Pacific.

In many of the addresses that have been made during the past summer, on the Centennial occasion, the shortcomings of the United

States in extending the boundaries of scientific knowledge, especially in the physical and chemical departments, have been set forth. "We must acknowledge with shame our inferiority to other people," says one. "We have done nothing," says another. Well, if all this be true, we ought perhaps to look to the condition of our colleges for an explanation. But we must not forget that many of these humiliating accusations are made by persons who are not of authority in the matter; who, because they are ignorant of what has been done, think that nothing has been done. They mistake what is merely a blank in their own information for a blank in reality. In their alacrity to depreciate the merit of their own country, a most unpatriotic alacrity, they would have us confess that for the last century we have been living on the reputation of Franklin and his thunder-rod.

Perhaps, then, we may without vanity recall some facts that may relieve us in a measure from the weight of this heavy accusation. We have sent out expeditions of exploration both to the Arctic and Antarctic seas. We have submitted our own coast to an hydrographic and geodesic survey, not excelled in exactness and extent by any similar works elsewhere. In the accomplishment of this we have been compelled to solve many physical problems of the greatest delicacy and highest importance, and we have done it successfully. The measuring-rods with which the three great base-lines of Maine, Long Island, Georgia, were determined, and their beautiful mechanical appliances, have exacted the publicly-expressed admiration of some of the greatest European philosophers, and the conduct of that survey their unstinted applause. We have instituted geological surveys of many of our States and much of our Territories, and have been rewarded not merely by manifold local benefits, but also by the higher honor of extending very greatly the boundaries of that noble science. At an enormous annual cost we have maintained a meteorological signal system, which I think is not equaled and certainly is not surpassed in the world. Should it be said that selfish interests have been mixed up with some of these undertakings, we may demand whether there was any selfishness in the survey of the Dead Sea? Was there any selfishness in that mission which a citizen of New York sent to equatorial Africa for the finding and relief of Livingstone, any in the astronomical expedition to South America, any in that to the valley of the Amazon? Was there any in the sending out of parties for the observation of the total eclipses of the sun? It was by American astronomers that the true character of his corona was first determined. Was there any in the seven expeditions that were dispatched for observing the transit of Venus? Was it not here that the bi-partition of Bela's comet was first detected, here that the eighth satellite of Saturn was discovered, here that the dusky ring of that planet, which had escaped the penetrating eye of Herschel and all the great European astronomers, was first seen? Was it not by an American telescope that the companion

of Sirius, the brightest star in the heavens, was revealed, and the mathematical prediction of the cause of his perturbations verified? Was it not by a Yale College professor that the showers of shooting-stars were first scientifically discussed, on the occasion of the grand American display of that meteoric phenomenon in 1833? Did we not join in the investigations respecting terrestrial magnetism instituted by European governments at the suggestion of Humboldt, and contribute our quota to the results obtained? Did not the Congress of the United States vote a money-grant to carry into effect the invention of the electric telegraph? Does not the published flora of the United States show that something has been done in botany? Have not very important investigations been made here on the induction of magnetism in iron, the effect of magnetic currents on one another, the translation of quantity into intensity, and the converse? Was it not here that the radiations of incandescence were first investigated, the connection of increasing temperature with increasing refrangibility shown, the distribution of light, heat, and chemical activity in the solar spectrum ascertained, and some of the fundamental facts in spectrum analysis developed long before general attention was given to that subject in Europe? Here the first photograph of the moon was taken, here the first of the diffraction spectrums was produced, here the first portraits of the human face were made—an experiment that has given rise to an important industrial art!

Of our own special science, chemistry, it may truly be affirmed that nowhere are its most advanced ideas, its new conceptions, better understood or more eagerly received. But how useless would it be for me to attempt a description in these few moments of what Prof. Silliman, in the work to which I have already referred, found that he could not include on more than 100 closely-printed pages, though he proposed merely to give the names of American chemists and the titles of their works! It would be equally useless and indeed an invidious task to offer a selection; but this may be said, that among the more prominent memoirs there are many not inferior to the foremost that the chemical literature of Europe can present. How unsatisfactory, then, is this brief statement I have made of what might be justly claimed for American science! Had it been ten times as long, and far more forcibly offered, it would still have fallen short of completeness. I still should have been open to the accusation of not having done justice to the subject.

Have those who gloat over the shortcomings of American science ever examined the Coast Survey reports, those of the Naval Observatory, the Smithsonian contributions, those of the American Association for the Advancement of Science, the proceedings of the American Academy of Arts and Science, those of the American Philosophical Society, the Lyceum of Natural History, and our leading scientific periodicals? Have they ever looked at the numerous reports pub-

lished by the authority of Congress on geographical, geological, engineering, and other subjects—reports often in imposing quartos magnificently illustrated.

Not without interest may we explore the origin of the depreciation of which we thus complain. In other countries it is commonly the case that each claims for itself all that it can, and often more than is its due. Each labors to bring its conspicuous men and its public acts into the most favorable point of view; each goes upon the maxim that a man is usually valued at the value he puts upon himself. But how is it with us? Can any impartial person read without pain the characters we so often attribute to our most illustrious citizens in political and, what is worse, in social life? Can we complain if strangers accept us at our own depreciation, whether of men or things?

We need not go far to detect the origin of all this—it is in our political condition. Here wealth, power, preferment—preferment even to the highest position of the nation—are seemingly within the reach of all, and in the internecine struggle that takes place every man is occupied in pushing some other man into the background.

I fear that in political life there is no remedy for this, such is the violence of the competition, so great are the prizes at stake. But in the less turbulent domain of science and letters we may hope for better things. And those who make it their practice to decry the contributions of their own country to the stock of knowledge may perhaps stand rebuked by the expressions that sometimes fall from her generous rivals. How can they read without blushing at their own conduct such declarations as that recently uttered by the great organ of English opinion, the foremost of English journals? The *Times*, which no one will accuse of partiality in this instance, says: "In the natural distribution of subjects, the history of enterprise, discovery, and conquest, and the growth of republics, fell to America, and she has dealt nobly with them. In the wider and multifarious provinces of art and science she runs neck and neck with the mother-country, and is never left behind!"

There are among us some persons who depreciate science merely through illiterate arrogance; there are some who, incited by superficiality, dislike it; there are some who regard it with an evil eye, because they think it is undermining the placid tranquillity they find in life-long cherished opinions. There are some who hate it because they fear it, and many because they find that it is in conflict with their interests.

But let us who are the servants of Science, who have dedicated ourselves to her, take courage. Day by day the number of those who hold her in disfavor is diminishing. We can disregard their misrepresentations and maledictions. Mankind has made the great discovery that she is the long-hoped-for civilizing agent of the world. Let us continue our labor unobtrusively, conscious of the integrity of

our motives, conscious of the portentous change which is taking place in the thought of the world, conscious of the irresistible power which is behind us! Let us not return railing for railing, but, above all, let us deliver unflinchingly to others the truths that Nature has delivered to us!

The book of Nature! shall not we chemists, and all our brother-students, whether they be naturalists, astronomers, mathematicians, geologists, shall we not all humbly and earnestly read it? Nature, the mother of us all, has inscribed her unfading, her eternal record on the canopy of the skies, she has put it all around us on the platform of the earth! No man can tamper with it, no man can interpolate or falsify it for his own ends. She does not command us what to do, nor order us what to think. She only invites us to look around. For those who reject her she has in reserve no revenges, no social ostracism, no *index expurgatorius*, no *auto-da-fé!* To those who in purity of spirit worship in her heaven-pavilioned temple, she offers her guidance to that cloudy shrine on which Truth sits enthroned, "dark with the excess of light!" Thither are repairing, not driven by tyranny, but of their own accord, increasing crowds from all countries of the earth, conscious that, whatever their dissensions of opinion may heretofore have been, in her presence they will find intellectual concord and unity.

MENTAL OVERWORK.

By ROBERT FARQUHARSON, M.D.

TO hit off the happy medium between over- and under-work is no easy task even to those who have the necessary knowledge, on the one hand, and the liberty to arrange their own scheme of occupation, on the other. But, for one person who is injured by doing too much, I quite believe with Dr. Wilkes that many may be found who are sustaining serious damage from not having enough mental stimulus. The listless vacuity in which so many of the well-to-do classes spend their lives, the want of any incentive to exertion, and the absence of any attempt at real thought which the wide-spread prevalence of ready-made opinions in our periodical literature directly encourages, must cause more or less degeneration of intellectual power. Under these conditions the brain gradually loses its healthy tone, and, although quite equal to the daily calls of a routine and uneventful existence, it is unable to withstand the strain of special sudden emergency, and, when a heavy load of work is unexpectedly thrown upon it in its unprepared state, then we see all the worst consequences of what may be called overwork develop themselves. It is no uncom-

mon experience to meet with cases in which damage has been done to the bodily constitution by indulging too recklessly in athletic exercises and active physical exertion when the muscles have become flabby and feeble from disuse. A man accustomed to sedentary pursuits takes suddenly to boating or running, or the horizontal bar, and, if he escapes straining his heart, he is certain to make himself stiff and uncomfortable. Or he has been told that there is nothing like Switzerland for reviving the faded Londoner, so, without the slightest attempt at preparation, he dovotes himself enthusiastically to climbing ice-peaks and traversing snow-passes; and, when his brief holiday is over, he comes back, worn and jaded, and astonished to find that the glacial air, which has proved so beneficial to many, has done nothing for him.

Now, the fault here lies in the want of proper preliminary training. Even as we do not prescribe quinine as a tonic until we have ascertained that the digestive functions of our patient are in good working order, so it is most improper for any one to attempt active muscular exertion without bracing up the previously-unused muscles by carefully-graduated exercise. And in mental operations the same analogy holds good. If the brain is not habituated to the constant gymnastic influence of steady work, it is liable to give way or suffer more or less injury from any sudden and spasmodic effort. If, on the other hand, however, its healthy nutrition is insured by the free supply of pure blood and the true balance between destruction and repair, we shall find ourselves in possession of an organ which will bear almost any amount of steady strain, so long as certain conditions are fulfilled. So long as a brain-worker is able to sleep well, to eat well, and to take a fair proportion of out-door exercise, it may safely be said that it is not necessary to impose any special limits on the actual number of hours which he devotes to his labors. But when what is generally known as worry steps in to complicate matters, when cares connected with family arrangements, or with those numerous personal details which we can seldom escape, intervene, or when the daily occupation of life is in itself a fertile source of anxiety, then we find one or other of these three safeguards broken down. Probably the man of business or the successful advocate cannot shake himself free from his business thoughts at night. Slumber becomes fitful and disturbed. The sympathetic system, unsettled by the mental strain, brings about various defects in nutrition; the appetite fails, and the vigor of the nervous tissues is no longer able to withstand the endless round; and then we meet with the sleeplessness, the dyspepsia, the irresolution, the irritability, and the depression, which are among the chief miseries of those who we are in the habit of saying are overworked.

Now, the *Lancet* has lately laid before its readers some interesting statements which would lead us to believe that damage is being done to many boys in preparatory schools by the strong competition

imposed upon them by the entrance-examination to the larger institutions, and by the ambition of their masters, who hope to derive profit and honor from their success. This is indeed a serious consideration, and the possibility of a large section of our most promising lads being thus mentally stunted in early life would demand instant interference did we deem the charge fully proved. Now, with all deference, I would venture to express my opinion, based on some experience, that, although we must not neglect so timely a warning of probable rocks ahead, there is no specific evidence of present injury. During my residence at Rugby I was in medical charge of several preparatory schools where the educational standard was very high, and where the success was proportionate when the boys came to be drafted off into the big school. I may truly say that no case was brought under my notice during the space of three years which I could in any way trace to overwork. And this I attribute to the perfect manner in which the counterbalancing conditions of health were sustained, the good food, satisfactory hygienic conditions, ample time for recreation and active sports, and frequent holidays. Boys of that age do not fret or worry over their work—they throw it off in their intervals of repose, sleep well, eat well, play well, and so do not suffer. Depend upon it, it would be little to the credit of any proprietor of a private educational establishment were he to neglect the laws of health, and send his boys home enfeebled and worn out from too heavy mental strain.

As regards the larger public schools the same remarks apply, and I met with very few instances at Rugby of any bad consequences from overwork; and in the three or four well-marked cases which came under my care I was enabled to detect some other equally operative cause which predisposed to the seizure. Thus one lad, ambitious of distinction both at classics and foot-ball, had undergone violent physical exertion while exhausted by study, and the supply of nerve-force, not being available for this double strain, gave way, and a sharp, feverish attack ushered in long-continued mental prostration. A second boy, who suffered from a precisely similar attack, had been sitting up late at night, and felt some anxiety about a future prize; and the third lad, who completes the catalogue, had also consumed the midnight oil to an undue extent. But, as a general rule, the typically healthy life and surroundings of our great public schools enable their inmates to withstand a much greater amount of work than lads brought up at home, who are often unduly spurred on, and who have not the healthful stimulus of enforced active exercise. Among this class I have seen a much greater proportionate extent of temporary break-down from the effects of mental exertion too long sustained and too little relieved.

Although the standard of the School Board is not very high, we may foresee a possible source of danger in forcing the minds of wretchedly feeble, ill-fed, and ill-housed children suddenly into edu-

cational grooves. I think I have seen an increase of headaches and nervous complaints among the children of the poor since compulsory attendance has been enforced, and would only wish to record the warning against attempts to make bricks too rapidly out of the straw which has fallen into our hands to mould for good or evil.

Coming to the universities, cases of overwork are, I imagine, more common there, for not only are the young men at a more sensitive period of life, but they naturally feel that to many of them this is their great opportunity—the great crisis of their existence—and that their success or failure will now effectually make or mar their career. Here the element of anxiety comes into play, sleep is disturbed, exercise neglected, digestion suffers, and the inevitable result follows, of total collapse, from which recovery is slow, and perhaps never complete. Others, again, endeavor in their last year to make up for the frivolities of the first two; but when Dr. Morgan takes up for us the history of the intellectual life of the universities in the same exhaustive way in which he has traced the statistics of their leading oars, I doubt not that we shall find that the indictment of overwork brought against them has also been much exaggerated.

But, although less common than is generally supposed, instances of this class of break-down do occur from time to time, and I should like to ask those who have devoted special attention to nervous diseases what is their view of the pathology of such cases as the following:

A student, or an artist, or the master of a public school, after a very heavy mental strain, suddenly gives way, and is seized with sharp illness, comparable in some degree to the old-fashioned brain-fever. On his recovery he takes a prolonged rest, and his general health is perfectly restored; he looks strong and hearty, and has even gained flesh, and so at last he thinks himself well enough to resume his duties. But it is found that, although he can do a little, anything like his old power of concentrated attention and steady application is gone, and if he tries to do a full day's work, he breaks down again in minor degree, and at last is obliged to content himself with taking only a very slight share in those occupations in which he used specially to excel, and in many cases his powers are never fully regained. With all the outward appearances of health, he well knows the very narrow limits within which he is now compelled to restrict his intellectual exercise. What, then, is the precise pathological condition here? Various diseases are also known to weaken the mental powers for long periods after convalescence is established, and of these scarlet and enteric fevers rank among the principal.—*Lancet.*

THE MEDICAL PROFESSION IN MODERN THOUGHT.[1]

By HENRY MAUDSLEY, M. D.,

PROFESSOR OF MEDICAL JURISPRUDENCE IN UNIVERSITY COLLEGE.

GENTLEMEN: It has devolved upon me this year to deliver, in accordance with prescribed custom, the introductory lecture to the course of systematic instruction upon which you are about to enter. At the outset I am free to confess that I have been not a little perplexed and troubled about what I ought most fitly to say; like many of my predecessors in the office, I have found the choice of subject beset with difficulties, and I have small hope that I can say anything to redeem the usual barrenness of the occasion. It is just twenty-five years since I, sitting where one of you now sits, listened to my first introductory lecture from the lips—mute, alas! now forever—of one whose pure and gentle nature attracted in no common measure the esteem, the respect, and the affection, of all who knew him. I mean the late Dr. Parkes. It is an extraordinary, almost an unparalleled, thing to say of any man, that no one who heard mention made of his name ever heard an ill word said of him; but I believe that this was strictly true of Parkes. His life, lovely and of good report throughout, was indeed a practical refutation of the saying, "Woe unto you when all men shall speak well of you." If I could sketch in striking outline the features of his character, and set forth justly the pure course of his life—showing with what patient industry and entire sincerity of insight he worked in scientific inquiries, how upright he was in all his ways, and how kindly considerate to others: how he lived, and how, his work faithfully done, he died—I should probably give you an inspiring and most useful introductory lecture; for I should present to you a noble example, the labor to imitate which would be an excellent scientific and moral training. But that has been done with more or less completeness by various persons, though not always, perhaps, with the discrimination which one would wish to see shown in the appreciation of such a character. It is a very amiable wish to say everything good of a man when he is silent forever, and the vocabulary of flattering words is apt to be exhausted in the endeavor to gratify this feeling, the effect sometimes being that the actual features of the character are blurred, and something which is intended to be very perfect, but which is very unreal, is produced. It seems to me that the distinguishing characteristic of Parkes, that by which mainly he was what he was, was not so much originality or height of intellect (in this others have equaled or surpassed him) as the height of his moral stature—in this

[1] Introductory lecture delivered at University College, London, October 2, 1876.

perhaps he has hardly ever been surpassed; and that the grand lesson to be learned from the extraordinary esteem and affection which he inspired, from the infection of earnestness and sincerity which spread from him, and from the elevating influence which he exerted upon those who were brought into close converse with him, is a lesson which the history of human progress through the ages teaches too, and which needs much to be had in remembrance in these days of the glorification of science. It is this: that great as is knowledge, the moral nature is greater still; that the impulses of evolution which move the world come not from the intellect, but from the heart; that he who would work upon the hearts of others must speak to them from the heart; that everywhere and always we have to recognize the predominance of the heart over the intellect.

Perhaps if I could recall vividly the thoughts and feelings of my mind when sitting there twenty-five years ago, and compare, or rather contrast, them with my thoughts and feelings now, I might extract from the comparison the essence of a quarter of a century's experience of life, and impart to you what it will probably take you a quarter of a century to acquire. But I am doubtful whether that would not be to do you a great disservice, for I could hardly fail thereby to take much heart out of your hopes, much ardor out of your enthusiasm, much energy out of your exertions. Moreover, I feel pretty sure that what I could say, however wisely it might be said, would not be of the least use to you. Neither nations nor individuals profit much by the experience of other nations or of other individuals; they must go through their experience for themselves, learning through suffering, succeeding through blundering, attaining to the calmness of wisdom through the fevers of passion; and many times only when opportunities are gone, and their consequences in irrevocable operation, is it seen perhaps how much better use might have been made of them. No doubt there is wise purpose in this inability of the young to take home and assimilate the experience of those who are older; for I know not how they could preserve that enthusiasm and freshness of spirit which make life itself a joy, and beguile them to pursue with eagerness its aims, were their illusions destroyed, as illusions one after another are destroyed by experience. In the full stream of its young energy life is too little conscious for reflection; to live is happiness enough; in its later stages more and more, as the heart is applied to know wisdom, is it felt to be vanity and vexation of spirit. This may seem a hard doctrine, but it is true; it has been the experience of the greatest sages of all times; it is the central thought of the great religious systems of the world.

Let me pass, however, from reflections which, if pursued, might tend to dishearten rather than to hearten you, and endeavor to show you that, as things go, you have made a good choice of a profession for your life's work. I should be thought to have ill discharged the

function of introductory lecturer by preaching a gospel of pessimism, and inoculating you at the outset of your career with a despair of the littleness of life. Whatever the motive which has made you choose the medical profession as your life-career—and I suppose this has in most cases been the advice or example of others, or perhaps some quite accidental influence; for it is a startling consideration on what little circumstances the great issues of life often turn—you will not, I think, ever have cause to regret your choice if you look to the higher aim of it, and to that which is the proper end of human life. But on that condition only. It is not a profession which one who is ambitious of worldly distinction, or eager to accumulate much riches, should choose. You might, with prudence and industry, get vastly richer on the Stock Exchange or in commerce in a short time than you will probably after the labor of a long life in medical practice; and if you would aspire to gain a peerage or other ornamental thing of that kind, you would have done better to have gone into the army, and to have set before you as an aim, not the saving but the destruction of life; or to the bar, and have sold the highest exertions of your intellect to advocate the cause, whether the cause of the oppressor or of the oppressed, for which you were retained. Peerages don't come our way, and I am heartily glad they do not, for I much fear that there would not be the strength of mind to reject them; that a pitiful social ambition might tempt us to spoil the simple intrinsic nobility of our vocation with the outworn decorations of a childish stage of human progress. If medical practice be pursued as a mere means of money-getting, assuredly it causes the deepest demoralization of him who so uses it, as best things turned to basest ends breed the greatest corruption. He who deliberately applies himself to take the utmost advantage of the suffering and the feebleness of humanity, coming to him for aid in its anguish and its utter helplessness, in order to make his profit—and we may hope there are not many creatures of that vileness in the profession—may have large success in his low aim, but he discovers a meanness and a degradation of nature which are a grievous shame to his kind, and which devils might almost disdain.

But if you look to what is the true end of knowledge and work—to relieve the suffering and to minister to the comfort of man's estate, to lessen the sum of human sorrow on earth—you have chosen a profession which yields the fullest satisfaction to your aim and the largest scope to your work. We learn in order to act, the end of all knowledge being action; and the end of all action is to promote the welfare and the progress of mankind upon earth. In no profession are the opportunities of doing this good work so great and constant as in ours; to the least of us, as to the greatest, occasions of tender sympathy and patient help occur every hour in the daily routine of our work; and no profession, therefore, rests so little for appreciation upon any adventitious circumstance of time or place, or so little needs

extraneous titles of honor to give it dignity and respect. Put a doctor in the midst of the wildest savages, and they will respect the "medicine-man," when the lawyer's fluent sophistry and the preacher's pathetic eloquence would not gain them consideration, or even save them from death. Livingstone passed unharmed and esteemed among the savage tribes of Africa under the protection of his medical skill; and Christ himself cultivated the character and functions of a healer of disease, not only because in that capacity he went about doing good, but probably also, as De Quincey surmised, for the secret reason that he thus disarmed the jealousy and suspicion which the ruling authorities might otherwise have felt of the crowds which he drew about him. When the mighty fabric of the Roman Empire, penetrated by internal decay, at last fell to pieces under the successive assaults of the Goths, and the Vandals, and the Huns, many thousand persons were, as Gibbon tells us, taken captive and distributed through the deserts of Scythia; and it is interesting to note what was the relative value of persons under these circumstances. "The skill of an eminent lawyer would excite only their contempt or their abhorrence. The vain sophist or grave philosopher who had enjoyed the flattering applause of the schools was mortified to find that his robust servant was a captive of more value and importance than himself. But the merit of the physician was received with universal favor and respect; the barbarians who despised death might be apprehensive of disease." So long as man deems it the most important thing in the world to him that he should go on living—and he does that commonly as long as he is alive—so long will he hold in favor and esteem him whom he believes able to prevent or to mitigate the suffering of disease, and to keep at bay "the last enemy," death. It has always been so. "Honor a physician with the honor due unto him for the uses which ye may have of him; for the Lord hath created him."

Having seen how good a thing is the direct work of relieving suffering by medical art, let me now go on to point out that the training through which you go in order to fit yourselves to do this is excellently well adapted to make the most of your intellect as an instrument of knowledge. It seems to me that no education which is given anywhere, taking it all in all, is better than that through which it is necessary to go in order to become a thoroughly accomplished physician. You are brought into direct contact with the facts of Nature, face to face with them from the beginning of your course; step by step you advance in the practice of observation and reflection, from more simple to more complex phenomena, and so you learn to make the order of your ideas conform gradually to the order of Nature. That is real instruction; moreover, it is instruction at first hand. In intercourse with Nature, sophistry and pretense avail nothing; sincerity, and humility, and veracity of mind, are essential; we must learn patiently her laws, and, learning, obey them, or we ourselves, our con-

temporaries, or our posterity, will suffer infallibly from their violation. There is no possibility of hoodwinking those eternal laws which, in our dealings with them, never make a mistake and never overlook one, never forego an advantage, never shrink to exact retribution, never feel remorse. When a person leaves college with a very respectable knowledge of Greek and Latin authors, and with little or nothing more than that, it seems preposterous that he should think himself an educated person. If he has learned nothing about the stars above his head and the earth beneath his feet; nothing about the nature of the air which he breathes, of the water which he drinks, of the food which he eats; cannot tell why water rises in a pump, or how a man breathes, and why he dies if he cannot get air to breathe; knows nothing whatever of the laws of the world in which he lives and of which he is a part, he is surely a profound ignoramus, notwithstanding that he may be able to make indifferent Greek or Latin verses. I would not for a moment undervalue the priceless benefits of a knowledge of Greek and Latin authors; on the contrary, I am sure that a study of the works of these great minds of antiquity, full as they are of the rich stores of human observation and thought, expressed in the most chaste, concise, and finished language, produces a discipline of intellect and a refinement of culture which can be got in no other way, and the loss of which in youth nothing gained afterward will ever entirely compensate for; but I am sure also that if Plato or Aristotle, or any of those great thinkers of antiquity, were to live again now, he would look with amazement and compassion, if not with contempt, on men who are content that education should consist in studying only the writings of the past, in utter neglect of the wonderful works of Nature to which the later ages of mankind have gained access, and of the vast stores of knowledge which have been gradually accumulated by the patient labors of successive generations of men. He would be apt, I think, to say something of this sort: "Good Heavens! we lived more than two thousand years ago; have you in all that time gained no new experience of men and things which it would be well to make an essential part of the intellectual culture of your children? is it education enough for life now to let them learn from us what we thought of men and things more than two thousand years ago, and to train them in a study of the structure of our dead language?" To state the matter so, sufficeth to expose its absurdity.

Now, the training of a medical man, when thorough, is admirable in this respect, that it follows the order of Nature, beginning with the less complex and rising to the more complex sciences, using the lower as a ladder by which to mount up to the higher. Coming to his work, as he certainly should do, with a fair knowledge of mathematics and physics, he proceeds to the study of chemistry, and passes on thence to the study of physiology; so he lays deep and firm the scientific groundwork for the study of the disorders of the structure

and functions of the body, which is to be his ultimate special work. Without the foundations of the prerequisite studies he will not be a thoroughly well-grounded and cultivated physician, who may be relied upon to perfect his knowledge by experience through life, although he may no doubt be a fair practitioner in the routine which he has been taught, or, if he devotes himself to surgery, skillful as a mere operator. A knowledge of the simpler and more general science is an essential prerequisite to the study of the more complex and special science. Physics lie beneath chemistry; in physics and in chemistry we search for those intimate operations of matter which lie at the foundation of physiology; and physiology in its turn is essential to the construction of the more complex science which is concerned with man in his social relations—that is, sociology. And I may observe, by-the-way, that psychology, which is an important study for the man who has to put right the disorders of the minds and bodies of his kind, demands not only a thorough knowledge of physiology, but observation, also, of man in his social relations. Each science rests upon the one below it, but reflecting the increasing complexity of Nature as we rise from the movements of masses to the movements of molecules of matter, and to the combinations and relations of atoms, from dead again to living matter, from the simplest forms of life to complex organisms, and from organisms to the social union of organisms, contains in ascending scale something more than the science below it—something which constitutes its autonomy as a science. Physiology being placed in this scale, as you perceive, between chemistry and sociology, is on that account a most instructive study at the present time, when chemistry has made great progress toward scientific exactitude, and when the cultivation of the new field of social science is just being entered upon; there is no science, in fact, which yields such rich promise of large discoveries in the immediate future, and no science the discoveries of which, when applied to human needs, will do so much to lessen physical suffering. Fortunate are you, then, in the training which prepares you for the study, and in the lot which at this particular era has fixed your work in the pursuit, of a science which promises so great an abundance of good fruit.

One warning I would stop a moment here to urge. While recognizing the subordination of the sciences, we ought not to overlook the fact that all the sciences are at bottom artificial divisions; that the world is not divided rigorously into those different domains which we call physics, chemistry, physiology, and the like; that we make the divisions for our convenience according to the complexity of the phenomena, not because we discover them in Nature. Nature is one and continuous, and takes not the least notice of the arbitrary divisions which we find it necessary to make. It would seem a very obvious distinction between plant and animal; and yet if we push our

investigations into that border-territory of Nature where animal and vegetable life touch, we meet with so-called monads—the *Heteromita*, for example—which may be referred with equal justice to either kingdom; there are organisms which we think vegetable, having characters which we call animal, and organisms which we call animal, having characters which we think vegetable; there is, in truth, no line of demarkation, but instead an insensible series of gradations, and no man can say where the one kingdom ends and the other begins. In like manner, notwithstanding the seemingly gross and palpable distinction between living and dead matter, any one who sets himself to work to find out where life begins will be hard put to it to draw a line of separation, and more hard put to it when called upon to make good his division. Man himself, much as he makes of himself, is not separated from the rest of Nature by an impassable gulf; he modifies Nature largely, it is true, but the art by which he does that is Nature; he is a part of the order thereof—the latest product of the evolution which went on for countless ages before he appeared upon earth, which is going on now in his progress, his knowledge and his moral feelings being agencies in the process, and which, for anything we know, will go on for countless ages after the earth, which he has ceased to replenish and subdue, has fallen into the condition in which the moon now is, and rolls on its solitary way through space, a cold and desert globe, the tomb of all human aspirations, sorrows, sins, and achievements. In making use, then, of the arbitrary divisions of our sciences, we ought never to lose hold of the actual unity and continuity of Nature; never to overlook the fact that there is not a single truth in any science which has not its essential relations with the truths of all sciences; never to forget that the least things and the greatest are indissolubly bound together as equally essential elements of the intimately connected and mysterious whole which we call the universe. It may seem a fanciful saying, but there is a truth in it, that you cannot utter an exclamation, strike a note on a piano, move a grain of sand from its place, without affecting the entire universe.

Now the systematic training of the mind in conformity with the order of Nature, through patient observation and careful induction, the knowledge of Nature which is got by becoming, as Bacon says, her servant and interpreter, is a tedious business. Men, therefore, have gladly shirked it; they have found it much easier to attribute phenomena to some metaphysical entity which they have created out of a mental abstraction, or to invoke a supernatural cause to account for them, than to find out the explanation. In consequence of this habit of mind, which has had large operation in the past, a body of doctrine has grown up which, having had its day, is now fast becoming effete, but which men will not willingly part with—doctrine comparable, if I may use a physiological comparison, with those organs which, like the thymus gland, have their uses at a certain stage of

the body's development, but afterward, having no longer any function, undergo atrophy. Moreover, men have not only shirked positive inquiry from indolence, but have hated it from hostility. They dread the thought of being shown to be one with Nature, and repudiate with abhorrence the suggestion that their bodies and minds will ever receive scientific explanation; as if their bodies and minds would be degraded to something quite different from what they are by being understood like other natural phenomena and described in terms of scientific thought. The supposition strikes them as something like a blasphemy against the nobility of their nature. Hence there is a deep-rooted instinctive hostility to the science that has to do with man, which you will have to take account of in your careers—an hostility which has found partial expression, I think, in the anti-vivisection agitation. There was more in the fierceness of that agitation than a laudable feeling of compassion for the animals—an intensity of acridity betraying another origin. There was the energy of fear and hatred—fear and hatred of the science which threatens the dethronement of man from the pedestal of conceit upon which he has placed himself, and the destruction of some of his traditional beliefs. But a little reflection might serve to prove to those who are moved by these hostile apprehensions that they are possessed with an unreasoning fear, and are disquieting themselves in vain. Let them look beyond the dark circle of their self-love, and they will see that what is good in old creeds does not perish; that, although old forms vanish, as generations and nations pass away, that in them which gave life to them does not pass away, but puts on new forms and survives, as new generations and nations follow and carry onward the work of progress. Better would it be for them to seek for and foster the good which survives than to lament and defend the old which is corrupt.

Certainly science has not been careful to avoid occasions of offense in its progress, and of its method and pretensions its votaries have sometimes written in a strain which justly provokes scorn. While proclaiming, then, the praises of observation and induction, and enforcing the value of a mental training which is obtained by studying Nature after that method, let me interpose a few words of qualification, in order that I may not be misunderstood. I cannot help feeling that a great deal of questionable doctrine has been propounded concerning the so-called method of induction which science is enjoined rigidly to pursue, and that Bacon would have been aghast had he seen the absurdity which some persons in these days describe as his method, and the imbecile procedures of some of those who believe that they are following it. They talk, in fact, of the method of observation and induction as if it were something to conjure by; a mechanical process of knowledge-getting which rendered superior mental capacity unnecessary; a sort of intellectual ladder by which the most stupid beings, if they only planted it properly, might mount up into the

highest places of knowledge. That was not Bacon's notion of it: he perceived clearly enough that a man does not see with his eye, but through it; that seeing in the sense of observation is impossible unless there be behind the eye the intelligence to interpret what is presented to it. The simplest act of perception is indeed more than a mere matter of sense; it is an actual induction or inference in which an important element is contributed by the mind; you cannot look at an ox or an ass, and know either of them to be what it is, without making an induction—can't see, in fact, until you are trained to see. Scientific observation and experimentation—and experiment is only observation aided by artificial means—may be carried on to the last hour of your lives without any result of the least value if you have not a mind trained to interpret. Of what use is it to torture Nature by strange experiments if you don't understand her language? You might sacrifice a hundred dogs or cats in cruel experiments, and be not a whit wiser at the end of your awful labors. Nature does not vouchsafe an answer to a scientific inquiry unless the intelligent question be put, and the precise experiment made, as Bacon insisted, *ad intentionem ejus quod quæritur;*[1] and it is impossible to put the definite question, or to make the precise experiment, unless there be a prudently-formed hypothesis in the mind—that is to say, an hypothesis based upon previous careful training in observation of Nature's processes and sound reflection upon them. The mind must be informed by patient and sympathetic intercourse with Nature; it is enabled then to make new adjustments by means of the knowledge which it has gained through past adjustments—to frame a new and true theory applicable to new experiences by reason of being stored with sound theories derived from past experiences. We shall do well, then, not to be too much intimidated by what is sometimes said or written in praise of mere observation of so-called facts, and in dispraise of theory, or imagine that any facts can be truly observed, or any science prosecuted with success, unless the well-trained mind coöperates with the senses. As I have said elsewhere, "That some declaim so virulently against theory is as though the eunuch should declaim against lechery; it is the chastity of impotence." Happy is the observer who, when he sets to work, has a good theory in his mind. The mischief is when men theorize who have not been trained in habits of accurate observation, or, I might go a step further and say, who have not inherited from father or grandfather in the foundations of their nature the lines of veracity of observation and thought on which to develop; for when one notices how persons of a certain eager temperament go on discovering facts which are no facts, and, notwithstanding that they are brayed in the mortar of an annihilating criticism, are not in the least benefited by the discipline, one cannot help feeling that the observer, like the poet, is born, not made.

[1] With special reference to the point under investigation.

But it is time to return to the direct line of my argument. From what has gone before, it should appear at what an excellent place of advantage the order of studies for the medical profession is adapted to place you; how wisely it is arranged to train the mind for sound reflection upon those most complex phenomena of Nature with which the medical man has to deal—the phenomena of life in health and in disease; and how sadly wrong in theory and mischievous in practice he is likely to be who neglects to lay well the foundations of his mental training. If no practical result were to follow a medical education, if it were not pursued, as it is, for the purposes of the medical art, I believe that one who aspired to fit himself best to understand the world in which he lives, and the men with whom he has to do, could not do better than go through it; for it would be an excellent foundation on which to build afterward. The study of man cannot be undertaken with any satisfaction, or carried out with any completeness, except through a previous study of the nature of which he is the present culmination; it is certainly not possible to enter the chamber of the mind without passing through the antechamber of the body; and we cannot understand the body unless we understand a good deal of the processes and laws of Nature which lie beneath biology. So far, then, Mr. Lowe appears to be right when he regrets, as he is in the habit of doing, that he was taught so much classical knowledge and no science when he was educated, and contrasts the disadvantages under which he labored with the advantages which each student at a middle-class school now enjoys. Newspaper critics think that he is making jokes or firing off paradoxes, and would seemingly rather have Mr. Lowe as he is than Mr. Lowe as he might or would have been; but I am disposed to think that Mr. Lowe's insight has enabled him to see what his critics quite fail to see—that the statesman who has to deal with the relations of men to one another in the world would be better qualified for his work if he had a good fundamental knowledge of the laws of man's nature and constitution, and of the laws of the world in which he lives. The scientific statesman—when we get him—will hardly deem it his highest achievement to shrink scared from the grasp of a principle, or his supreme privilege and merit to wait patiently to catch the fitful gusts of an ignorant public opinion.

The application of the principle which I have been enforcing, of learning to know man through Nature, the thorough knowledge of his environment, and of those of his relations to it which constitute his life, must clearly be the foundation of a scientific medicine. Here, as elsewhere, prevision for the purposes of action is our aim; we observe and infer in order to foresee, and, foreseeing, to modify and direct; we conquer by obeying, gaining a knowledge of the phenomena of living beings in order to make ourselves masters of them, just as by a knowledge of physics and chemistry we gain a mastery over the phenomena of physical Nature. It is impossible to treat a sick person,

except in the most lamely empirical fashion, without a knowledge of the properties of the organism and of its relations to its environment; for our medical function is to remove the disorder of these relations, which is disease, and to restore the harmony, which is health. In past times it has been too much the practice to treat the body as if it were an entirely independent kingdom, without regard to its essential relations with surrounding Nature, and to try to drive out the enemy which was supposed to have taken possession of it, by pills and potions, as barbarous nations try to drive him out by charms and ceremonies. Now, however, in the recognition of the intimate and constant relations between the organism and its surroundings, we are awaking to juster views of our duties as observers, and of our work as curers of disease; but it is because of the absence yet of anything like exact knowledge in this respect that medical practice is defective, tentative, empirical, often mere guess-work, and that the most experienced physicians, waiting patiently on Nature, aim to do the least harm by the drugs which they employ.

But we are perceiving more clearly, day by day, a larger application of this principle of looking to the relations of man, to what is around him as well as to what is within him, in the fulfillment of the great purpose of preventing disease. It is in this direction that the future course of medicine lies clearly open, and to this end that we must work; it will rise to the true height of its great vocation when it watches over communities, and ministers to the welfare and development of the race. I am apt to think that we shall attain to earlier and larger success in preventing the diseases of communities than in curing the diseases of the individual, as men who had been seeing heavy bodies fall to the earth every moment of their lives discovered the law of gravitation for the first time when they began to observe the grand general motions of the heavenly bodies. Indeed, we have already had encouraging success. Look through the yearly death-list of this great city two hundred years ago, and you will find a large proportion of deaths ascribed to diseases which have now been robbed of their sting, if they are not quite extinct. Many persons died then, as "that chief of men," Cromwell, did, from ague. Where is the mortality of ague now? Ague has disappeared with the disappearance, through better drainage, of the damp fogs which occasioned it, as ghosts and other superstitions have vanished with the disappearance, before the light of knowledge, of the fogs of ignorance in which they were engendered. Bloody-flux or dysentery seldom occurs now in England, and is more seldom fatal, but it caused many deaths two hundred years ago. The ravages of small-pox were then terrible, hosts of victims being carried off by it, and many persons who escaped death bearing its marks in blind eyes and hideously-scarred features; but I think we may foresee a time when, Keighley guardians notwithstanding, small-pox will no more afflict a prudent people. Plague,

scurvy, and spotted fever, each of which then claimed regularly its yearly tribute of victims, are becoming almost diseases of the past, and one needs not a prophet's imagination to foresee a time when cholera, scarlatina, fever, phthisis perhaps, and other diseases, will be no more; when preventive medicine shall have reached such a degree of perfection that the occurrence of epidemic disease will be felt as a gross reproach to the community, and when there will be comparatively little for the practitioner to do in the treatment of particular disease. It is unfortunate truly, as it is sadly unseasonable, that just when we see before us this fairer prospect, and when an encouraging beginning of progress has been made under the auspices of Mr. Simon and his well-organized staff, he should have been driven from office and his office abolished. But one instance more of the difficulties with which progress has to contend from the selfish intrigues and obstructive apathy of mankind!

You may be disposed perhaps to smile at my outlook as fancifully bright, and befitting only the imaginative flights of an introductory lecture. From the beginning, it may be said, men have, through unrestrained indulgence of their passions, generated disease, and however pure their surroundings may be made, they will go on doing the same thing: were a clean sweep made of all disease from the face of the earth to-morrow, they would breed it afresh before to-morrow's morrow. No doubt, as they are constituted and trained at present, they would be apt to do so; but one may hope that the medical science of the future—and here I would carry your imaginations a little way with me—will have a great deal to say in the way of instruction respecting the highest concerns of man's nature, and the conduct of his life; that it will enter a domain which has hitherto been given up exclusively to the moral philosopher and the preacher. I don't propose or suppose that we shall ask these gentlemen to step down from their platform, saying to them something of this kind: "You have been preaching wisdom and goodness of conduct for some thousands of years, and you haven't made much of it. Certainly one result thus far is striking enough: that men are devoting their eagerest energies to making the most destructive guns, and are conferring their greatest honors and applause on those who use them with the most destructive effects. For months, until quite lately, the soil of Eastern Europe was deluged with blood, shed amid unspeakable atrocities, in an entirely needless war, which your statesmen, presumably the highest products of the culture of your epoch, could or would do nothing to check. Stand aside, then, and let us try our method." To speak so would be as foolish as it would be arrogant; but we may perhaps, without undue presumption, promise them that, if they will learn and use the results of our method, they will have a deeper and more stable foundation in the constitution of human nature for their teaching than they have now, and will add much to the effi-

cacy of it by enforcing motives which will touch more keenly the springs of human conduct than those which they present. Now let me indicate very briefly, as must needs be, the method by which medical science is to advance to take possession of this higher ground.

Starting with the trite maxim that before we can act we must learn, it is obvious that, before we can teach men to act with more wisdom than they have done in the past, we must give them a better knowledge of their own nature and relations than they have had. This we propose to do by the patient and steadfast application of the method of observation and induction, which has served us so well in the subordinate branches of science, to the highest phenomena of man's being—his thoughts, feelings, and conduct. The problem is the same here, in fact, as in the lower sciences—to observe in order to foresee, and to foresee in order to modify and direct; and the method is the same. Admitting, as I see not how we can help doing scientifically, that a process of evolution has gone on in Nature, and that man, as he now is, is a product of the past carrying on this process in his progress to a higher purpose in the future, it is a natural conclusion that he must, as a part of Nature, be studied by the same method as the rest of Nature. We have to search back and find out how he came to be what he is by looking to the historical evolution of the race from its earliest known conditions, and by tracing in the development of the organism the operation of laws which we discover at work under less complex conditions in the rest of Nature. When we do that, we find the best reason to believe that the highest faculties of his mind, his intellect, and his moral feelings, have not been implanted ready-made in his nature at any period of its history, but have been the slowly-won results of the accumulated experiences of the race transmitted by hereditary action: that is the lesson which observation and induction, applied to the investigation of the origin and development of man's higher nature, teach with an authority which cannot be gainsaid from any standpoint of positive knowledge. I could have wished, had I had time, to have shown you how some phenomena of mental disease, which may be looked upon in this relation as instructive experiments of Nature made for us in a domain where we cannot make them for ourselves, confirm the induction which has been reached by observation of human development, both in the individual and in the race. But I must leave that unsaid, and restrict myself to the conclusion as regards conduct which results from the acknowledgment that the latest and best acquisitions of man have come to him by a process of ordinary development through the ages. For the problem of to-day is truly no longer the schoolmen's much-vexed question of the origin of evil, but the question of the origin and growth of good. Our plain duty is to find out the laws which have been at work in that process, and to continue it—to carry on, by deliberate method, with conscious purpose, the development

which has been going on through past ages irregularly and blindly. The time, in fact, has come when mankind should awake to the momentous reflection how great is the power which it may exert over its own destiny, and to the resolution methodically to use it. In fulfilling this paramount duty, upon whom will the function of inquiry and instruction immediately rest, but upon those who make the laws of vital development and function their study, and the application of the knowledge to further the well-being and development of the organism their work? Clearly, the medical investigator need not lapse into despair because he has no new conquests to make.

You will not be long in practice before you will have many occasions to take notice how little people ever think of the power which they have over their own destiny and over the destiny of those who spring from them—how amazingly reckless they show themselves in that respect. They have continually before their eyes the fact that by care and attention the most important modifications may be produced in the constitution and character of the animals over which they have dominion—that by selective breeding an animal may almost be transformed in the course of generations; they perceive the striking contrast between the low savage with whom they shrink almost from confessing kinship and the best specimens of civilized culture, and know well that such as he is now such were their ancestors at one time; they may easily, if they will, discover examples which show that by ill living peoples may degenerate until they revert to a degraded state of barbarism, disclosing their former greatness only in the magnitude of their moral ruins;—and yet, seeing these things, they never seriously take account of them, and apply to themselves the lessons which lie on the surface. They behave in relation to the occult laws which govern human evolution very much as primeval savages behaved in relation to the laws of physical Nature of which they were entirely ignorant—are content with superstitions where they should strive to get understanding, and put up prayers where they should exert intelligent will. They act altogether as if the responsibility for human progress upon earth belonged entirely to higher powers, and not at all to themselves. How much keener sense of responsibility and stronger sentiment of duty they would have if they only conceived vividly the eternity of action, good or ill; if they realized that under the reign of law on earth sin and error are inexorably avenged, as virtue is vindicated, in its consequences; if they could be brought to feel heartily that they are actually determining by their conduct in their generation what shall be predetermined in the constitution of the generation after them! For assuredly the circumstances of one generation make much of the fate of the next.

In the department of medical practice in which my work mainly lies I have this amazing recklessness strongly impressed upon me; for it occurs to me, from time to time, to be consulted about the propri-

ety of marriage by persons who have themselves suffered from insanity, or whose families are strongly tainted with insanity. You will not be surprised to hear, I dare say, that I don't think any one who consults me under such circumstances ever takes my advice except when it happens to accord with his inclination. The anxious inquirer comes to get, if he can, the opinion which he wishes for, and, if he does not get that, he goes away sorrowful, and does just what his feelings prompt—that is, gets married when he has fallen in love, persuading himself that Nature will somehow make an exception to inexorable law in his favor, or that his love is sufficient justification of a union in scorn of consequences. Certainly, I have never met with so extreme a case as I chanced to light upon in a book a short time ago. "I actually know a man," says the author, "who is so deeply interested in the doctrine of crossing that every hour of his life is devoted to the improvement of a race of bantam fowls and curious pigeons, and who yet married a mad woman, whom he confines in a garret, and by whom he has insane progeny." But I have met with many instances which prove how little people are disposed to look beyond their immediate gratification in the matter. If it were put to two persons passionately in love with one another that they would have children, one of whom would certainly die prematurely of consumption, another become insane, and a third, perhaps, commit suicide, or end his days in workhouse or jail, I am afraid that in three cases out of four they would not practise self-denial and prevent so great calamities, but self-gratification, and vaguely trust "the universal plan will all protect!"

Those who pay no regard in marriage to the evils which they bring upon their children, or in their lives to the sins by which the curse of a bad inheritance is visited upon them, may plead in excuse or extenuation of themselves the vagueness and uncertainty of medical knowledge of the laws of hereditary action. We are unable to give them exact and positive information when they apply to us, and they naturally shelter themselves under the uncertainty. Were our knowledge exact, as we hope it will some day be, we could foretell the result with positive certainty in each case, and so speak with more weight of authority. It is one of the first and most pressing tasks of medical inquiry to search and find out the laws of heredity, mental and bodily, in health and in disease, and, having discovered exactly what they are, to apply the knowledge purposely to the improvement of the race—that is, to prevent its retrogression and to promote its progress through the ages. I see no reason to doubt that by discovery of these laws and intelligent practical use of our discoveries we might in the fullness of time produce, if not a higher species of beings than we are, a race of beings, at any rate, as superior to us as we are superior to our primeval ancestors; the imagination of men seems, indeed, in the gods which they have created for themselves, to have

given form to a forefeeling of this higher development. But I will not pursue this pregnant matter further now; I have touched upon it only for the purpose of illustrating the large scope of the medical work of the future, which is to discover those laws which have been in operation through the past to make man the superior being which he is, and to determine his future action in intelligent conformity with them; not only to cure disease of body and mind, as it has aimed to do in the past, and to prevent disease, as its larger aim now is, but to carry on the development of his nature, moral, intellectual, and physical, to its highest reach.

So much, then, concerning the three topics on which I have proposed to myself to discourse in this lecture—namely, the nobility of your direct function as healers of disease, the excellence of the method of medical study as a means of intellectual and moral training, and its fruitfulness in benefits to mankind, and the grandeur and the reach of its aspirations for the future. Let me hope that I have, in fulfillment of my design, said enough to satisfy you that you have made a good choice of a profession for your life's work. Having chosen, it remains only that you should justify your choice by your work, so that it may be said of each of you, when his long day's task is over and the night has come, that he was in his right position in the world, and made a right good use of it. Life has its three stages —youth, manhood, and old age; let it be your anxious care now, in the first stage of joy and hope, so to pass the second stage of work and duty that the last stage may not be a long regret.

I will ask your indulgence only for a few minutes more, while I detain you for one or two final reflections of what I may call an inhibitory character. In pursuing resolutely the course of scientific inquiry which I have indicated, it must needs be that offenses sometimes occur, for we can hardly fail to come into collision with some of the prejudices and traditions of mankind. I do not know how it is possible, for instance, to prosecute the physiological investigation of mind to its farthest reach without shaking the foundations of the metaphysical notions which have been held concerning it and its functions; and with the fall of these notions, long cherished of mankind, other notions that are bound up with them may totter to their fall. But, if this must be, we shall do well to acknowledge it more in sorrow than in anger. Let us not rush with eager fury and exultant clamor to the work of destruction; it behooves us, as products of the past, who will one day ourselves constitute the past, to deal gently and even reverently with it. We cannot break with it if we would, nor should we if we could. The very language which we use we owe to the slow acquisitions of generations which have preceded us; we cannot compassionate or contemn them except in words for which we are indebted to them. There is hardly a word I have used in this lecture which, were its history searched out, does not mean

generations of human culture to which we are heirs. Seems it not, then, a wicked, almost a sacrilegious, thing to hasten with eager gladness to repudiate the past to which we owe everything, and to exult over the ruins of its beliefs? It is as if a son should rejoice over his father's feebleness, uncover his nakedness, and make scorn of his infirmities. As he who has been the best son is in turn the best father, so the generation which guards with respect the good which there is in the past, and puts gently aside that which is effete, will make the most stable progress in its day, and transmit the best inheritance to the generation which follows it. No doubt in the future, as in the past, the knowledge of one period will sometimes appear foolishness at a more advanced period of human evolution—the truth of one age become the laughing-stock of the next; but we may profitably reflect that decaying doctrine had its use in its day, and it may teach us modesty to consider that much which has its place in our mental organization now, and is serving its proper end in the development thereof, will one day probably be put aside as obsolete belief. Let it be our prayer that when that day comes, and this generation comes up for critical judgment as an historical study before the tribunal of posterity, it may be justly said of it that it has done as much for the progress of mankind as some of the generations upon which the wisest of us look back, perhaps, with indulgent compassion, and the unwise among us with foolish scorn.

There is nothing in the attitude of modern society toward science, cold and suspicious as it may sometimes be, which necessitates or warrants an arrogant, defiant, and aggressive spirit of hostility on its side. No great courage is required nowadays to declare a new truth, however hostile it may be to received belief, nor is any serious suffering entailed by the declaration; there is no need, therefore, for a scientific man to put on the airs of a martyr. He is a very little martyr who is persecuted only by the pens of unfriendly critics, and rather a pitiful object when he sits down by the wayside, and calls upon all them that pass by to behold and see how hardly he is used. It was very different when Science first made its voice heard; when, under the cruel persecutions of the Inquisition, Galileo unsaid with his tongue truths which his heart could not unsay, and that grand figure in the noble army of scientific martyrs, Giordano Bruno, went calmly and resolutely to the stake rather than utter one word of retractation. The saddest contemplation in the world, perhaps, is that of the brave who, like him, have died fighting in the battle for the cause that seemed to perish with them; whose lives of suffering and sore travail have set, often through cruel tortures, in black clouds of gloom which no ray of hope could penetrate. Theirs was not the laurel crown of victory after the agony of the struggle; no popular applause, no encouraging shout, greeted their ears as they sank down exhausted in death; the shouts which they heard were shouts of exe-

cration, and their crown was the martyr's crown of thorns. We have, happily, fallen on better days; the secrets which we win from Nature we may proclaim without fear, and in the confident assurance that, after being proved and tried, they will be accepted; we are fighting a winning fight, and the stars in their courses are with us. What cause, then, for arrogant self-assertion, overbearing aggression, and willful determination to seek occasions of offense? The advantages of our position and strength entail the responsibility of moderation and forbearance, for the strength is not our own—it is the power of the universe working in us to its higher ends.

One may esteem science duly, then, without feeling sympathy with the aggressive delight with which some persons accentuate its hostility to expiring doctrines, and exult in the overthrow of articles of faith which have sustained and solaced multitudes of men in the dark hours of life and in the darker hour of death. It can be no pleasure to a generous nature, inevitable though it be, to shatter the faith of even the poor Indian, who, driven from his hunting-grounds by the inexorable fate of a stronger race, looks upward with feeble faith to a Great Spirit, and forward with dim hope to the happy hunting-grounds far away where the sun goes down. To aspire to be the first to proclaim the downfall of a position of refuge to which men have clung with passionate earnestness for many generations seems to show "a pitiful ambition in the fool who uses it," a singular blindness to the essential continuity of development, a strange ignorance of what is the final end of all science. A scientific discovery is a very good thing in its way, but it is only a means to an end, after all—the improvement of man's estate—that is to say, his moral and intellectual as well as his material state; and when he who has been happy enough to discover a new metal or a new star or a new cell or a new salt magnifies himself mightily, and fondly dreams of an immortal fame, one cannot help some such feeling of the ludicrous as would be raised by the spectacle of a hodman who, having carried his brick to the building in course of construction, should call upon all the world to take notice of the wonderful work which he had done in architecture. Science has yet to realize, at any rate its cultivators seem oftentimes to forget, that its end must be constructive; that after analysis must come synthesis; that all the analytical work in the world will leave matters in a chaotic state until the constructive spirit, moving over their surface, shall organize the incoherent results, and make them serve for a higher social development. The problem is to make straight in the future a highway over which mankind may pass to a higher life. The philosopher who, with far-reaching eye, overlooks the relations of sciences; the poet who reveals subtilties of human feeling, gives lofty utterance to human sympathies with Nature, and infuses nobler aspirations into men; the preacher of human brotherhood who, inspired with strong moral feeling, proclaims the lessons of self-

renunciation and of duty to neighbor—these are brighter stars in the firmament of human genius than the scientific discoverer. The discovery of the law of gravitation is the grandest attainment of scientific thought; but can we justly compare the effects of that generalization upon human interests and happiness with the elevating influence which is exerted by the poetry of Isaiah or of Shakespeare upon multitudes throughout the world; which is perhaps being felt at this very moment by fireside or on sick-bed in distant lands—by the solitary dweller on the skirts of the vast forests of Western America, in the great lone land of Canada, in the farthest depths of the Australian bush? Science has not rendered the philosopher, the poet, and the moral teacher superfluous, nor will it ever supersede them; on the contrary, it will have need of them to attain to its own perfect working to the bettering of man's estate; and it may well seem to some that the time has come when its manifold scattered and somewhat anarchical results should be penetrated by the synthetic insight of the philosopher, be embodied in forms of beauty by the poet's imagination, and utilized by the moral teacher to guide and promote the progress of mankind. So long as man sees splendor in the starry heavens, beauty in the aspects of Nature, grandeur and glory in self-sacrifice, so long will he feel that his brief conscious life is but a momentary wavelet on the vast ocean of the unconscious; that there is in him the yearning of something deeper than knowledge, which "cometh from afar," and which the labored acquisitions of science will ever fail to satisfy.

ABOUT SHARKS.

SHARKS are usually spoken of as the most rapacious and abhorrent of sea-animals. That they are rapacious is undeniable, but why they are so is not generally considered. We will go a little into the matter. The shark, a fish of the family *Squalidæ*, when quite in his infant state, and only a few inches in length, exhibits a pugnacity almost without parallel for his age. He will attack fish two or three times larger than himself; or, if caught, and placed for observation on the deck of a vessel, he resents handling, and, with unerring precision, strikes a finger placed on almost any part of his body.

Two things contribute to the shark's determinate fierceness. In the first place, we may refer to his teeth, for of these engines of destruction Nature has been to him particularly bountiful; and this species of bounty he has a peculiar pleasure in exercising. If he could speak, he would probably tell us that, besides being troubled with his teeth, which he could not help keeping in use, he had been gifted with enormous abdominal viscera, and that, more particularly,

a third of his body is occupied by spleen and liver. The bile and other digestive juices which are secreted from such an immense apparatus, and poured continually into the stomach, tend to stimulate appetite prodigiously—and what hungry animal with good teeth was ever tender-hearted ? In truth, a shark's appetite can never be appeased; for, in addition to this bilious diathesis, he is not a careful masticator, but, hastily bolting his food, produces thereby not only the moroseness of indigestion, but a whole host of parasites, which goad as well as irritate the intestines to that degree that the poor squalus is sometimes quite beside himself for the torment, and rushes, like a blind Polyphemus, through the waves in search of anything to cram down his maw that may allay such urgent distress. He does not seek to be cruel, but is cruelly famished. "It is not I," expostulates the man in the crowd, "that is pushing; it is others behind me." The poor wretch must satisfy, not only his own ravenous appetite, but the constant demand of these internal parasites, either with dead or living food; and therefore it is that, sped as from a catapult, he pounces on a quarry, and sometimes gorges himself beyond what he is able to contain.

Having said thus much of the rapacious habits of the *Squalidæ*, we would have it remembered that every man's hand is against them, and that no tortures are considered too severe to inflict upon them when caught. If they are relentless to man and every living thing around them, their insatiable appetite renders them equally destructive to their own species, and we of the white population of this globe ought to recollect, with some show of gratitude, that they always prefer an African to a European; for, although they are fond of men of any color, a negro is to them as the choicest venison. Commerson tells us that one of the atrocious amusements practised on board slave-ships was to suspend a dead negro from the bowsprit, in order to watch the efforts of the sharks to reach him, and this they would sometimes effect at a height of more than twenty feet above the level of the sea. Wonderful are the tales that sailors tell of the various things that have been found in a shark's stomach, and it was thought that any substance that would enter its mouth was at all times acceptable. The following, which details a cruel trick, as described in the *Glasgow Observer*, dispels this illusion: "Looking over the bulwarks of the schooner," writes a correspondent to this journal, "I saw one of these watchful monsters winding lazily backward and forward like a long meteor; sometimes rising till his nose disturbed the surface, and a gushing sound like a deep breath rose through the breakers; at others, resting motionless on the water, as if listening to our voices, and thirsting for our blood. As we were watching the motions of this monster, Bruce (a little lively negro, and my cook) suggested the possibility of destroying it. This was briefly to heat a fire-brick in the stove, wrap it up hastily in some old

greasy cloths, as a sort of disguise, and then to heave it overboard. This was the work of a few minutes; and the effect was triumphant. The monster followed after the hissing prey. We saw it dart at the brick like a flash of lightning, and gorge it instanter. The shark rose to the surface almost immediately, and his uneasy motions soon betrayed the success of the manœuvre. His agonies became terrible; the waters appeared as if disturbed by a violent squall, and the spray was driven over the taffrail where we stood, while the gleaming body of the fish repeatedly burst through the dark waves, as if writhing with fierce and terrible convulsions. Sometimes we thought we heard a shrill, bellowing cry, as if indicative of anguish and rage, rising through the gurgling waters. His fury, however, was soon exhausted; in a short time the sounds broke away into distance, and the agitation of the sea subsided. The shark had given himself up to the tides, as unable to struggle against the approach of death, and they were carrying his body unresistingly to the beach."

Crouch, in his "Fishes of the British Islands," would indirectly claim some apology for the habits of the shark tribe; in reference to which he asks why the lion and the eagle should occupy the elevated places they do in popular estimation, as the king of beasts and monarch of the air. They live by the exercise of powers similar to those of the sharks, and if insatiable appetites are to take precedence, sharks ought to stand in the foremost rank.

The appearance of sharks occasionally upon our coast naturally creates a certain panic among bathers; and we may trace the breakage of the nets of our fishermen to their presence, among other causes. The six-gilled shark, or gray shark, is sometimes eleven or twelve feet in length, and is very destructive among the pilchards on the Cornish coast. The white shark is a formidable fellow; but although his class occasionally send over to our isles deputations of one or two, we have, fortunately, not had to record of late years such a visitation as that of 1785, when hundreds appeared in the British Channel. This individual is, perhaps, the most formidable of all the inhabitants of the ocean. Ruysch says that the whole body of a man, and even a man in armor, has been found in the body of a white shark. Captain King, in his "Survey of Australia," says he caught one which could have swallowed a man with the greatest ease. Blumenbach says a whole horse has been found in it; and Captain Basil Hall reports the taking of one, in which, besides other things, he found the whole skin of a buffalo, which a short time before had been thrown overboard from his ship. The blue shark is a horrible nuisance to the fishermen, but, fortunately, it is with us only in summer, when it makes itself known by hunting after the fish entangled in the nets, which it does by seizing both fish and net with its keen and serrated teeth, and swallowing fish and mesh together. As it is not always pleasant to have sharks following a ship, it cannot be too well

known that a bucket or two of bilge-water has been known to drive them off.

The shark tribe are remarkably retentive of life, and instances are related which would be almost beyond belief, if not vouched for by numbers of witnesses. For instance, an individual was caught with a line; its liver was cut out, and the bowels left hanging from the body, in which state the sailors, as an object of abhorrence, threw it into the sea. But it continued near the boat; and not long afterward it pursued and attempted to devour a mackerel that had escaped from the net. In another instance, a shark was thrown overboard after the head had been severed from the body; after which, for a couple of hours, the body continued to use the efforts of swimming in various directions—to employ the conjecture of a boy among the crew—as it it were looking for its head. Next, we have the thrasher, which has obtained the name of fox-shark, because of the shape of its tail. The title of thrasher, however, is most appropriate, from its habit of lashing the sea with its tail, by which it has been known to put to flight a herd of sportive dolphins, and even to fill the whale with terror. The porbeagle is another of the shark tribe, and is a common visitor on the western coasts in summer. Then follows that too plentiful and rapacious fish, the toper, known likewise as the white-hound, penny-dog, or miller-dog. However, as it swims deep, it does not do so much injury to the fishermen's nets as some of its congeners. Then we have the smooth-hound, or ray-mouthed dog, or skate-toothed shark, which are presumed to come from considerable distances, from the kind of hooks sometimes found in them, which resemble those used on the coast of Spain. They feed upon crustaceous animals, but will take a bait. The picked-dog, spur-dog, or bone-dog, but commonly known as the dog-fish, is the smallest, but unquestionably the most numerous of the shark tribe. It frequents our coasts all the year round, and even in the severest weather. Then there are the spinous shark, and Greenland shark, which will not be driven away from feeding upon the blubber of a stranded, half-immersed whale, although pierced with spears, but come again to the oleaginous banquet while a spark of life exists. The basking-shark also, occasionally, casts up on our coasts. It is of a large size, is capable of breaking a six-inch hawser, and is only taken with considerable difficulty. Then we have the rashleigh shark, the broad-headed gazer, and the hammer-head or balance-fish, which may be said to complete the list of these occasional unwelcome visitors to our shores.

And now that we have said so much that is prejudicial to the *Squalidæ* or shark community, let us see what we have as a set-off in their favor. As a food for man, the toper is found exposed for sale in the markets at Rome; and in Paris, that city of gastronomy, the small kinds of shark, when divested of their tantalizing titles, are to be detected as *entrées* in the *menu* of many of the most distinguished

families. For some years, the dog-fish has afforded lucrative employment during the whole of the summer to the fishermen from the Naze to the Cape. It is, however, mostly smoked, and in this way is considered rather a delicacy. It is also dried and split as stock-fish for consumption in the country, as well as for export to Sweden, where it is greatly appreciated. It is likewise elsewhere a common article of food, amid the choice of a variety of other fish, especially in the west of England, and, indeed, is valued by some who are far above the necessity of classing it with their ordinary articles of subsistence. It is used both fresh and salted, but, when eaten fresh, it is skinned before being cooked. Lacipede, who speaks slightingly of its flesh, informs us that, in the north of Europe, the eggs, which are about the size of a small orange, and consist solely of a pale-colored yolk, are in high esteem. If prejudice could be got over, there is no doubt they would form an agreeable as well as a nourishing article of food, as a substitute for other eggs in our domestic economy.

The shark-fishery is carried on in many parts of the Indian Ocean, and on the eastern coast of Africa, and recently it has been pursued on the coast of Norway. About Kurrachee, in India, as many as 40,000 sharks are taken in the year. The back-fins are much esteemed as a food delicacy in China, from 7,000 to 10,000 of these being shipped to that empire annually from Bombay. In Norway and Iceland the inhabitants make indiscriminate use of every species captured, hanging up the carcasses for a whole year, like hams, that the flesh may become mellow. The liver, however, appears to be strictly prohibited everywhere, as a dangerous article of food.

Mr. N. Brabazon, in his "Fisheries of Ireland," in allusion to the large shoals of sharks which pass annually along the west coast, on their way from the southern to the northern seas, speaks particularly of the basking shark: "These fish are worth from £35 to £50 each; and when so many as five hundred have been killed in one season, this class of fishing should be well attended to for the short season it lasts, if the weather is favorable to it, especially as it is at a time when other fish are out of season. The fishermen have a superstition that the fish will leave the coast if the bodies of those caught were brought to the shore." Mr. P. L. Simmons, in his "Waste Products and Undeveloped Substances," gives almost incredible statistics of the vast amount of fish-refuse which is either left to rot on the coasts and putrefy the air, or thrown back into the sea unutilized, both on our own and on foreign shores; and he significantly points to its value as a manure not far inferior to guano, of which this country alone requires 200,000 tons a year, and pays upward of £22,000,000. Would it not, therefore, be wise for enterprise and capital to begin to turn more attention to the manufacture of fish-guano, of which the *débris* of the North American fisheries, and those of the North Sea, would furnish ample material?—*Chambers's Journal.*

ABORIGINAL SETTLEMENTS OF THE PACIFIC COAST.

By PAUL SCHUMACHER.

IF we investigate the condition of the ground upon which we now find the ruined settlements of a former people on this coast, it cannot fail to convince us either that all such stations had been established on sandy ground, or that the ground had been artificially changed by sand carried thither when it was rocky or hard. Sandy soil was a necessity, that they might employ their rude and imperfect tools in the erection of houses partially dug in the ground and surrounded by embankments. It was also a requirement for cleanliness and health, owing to its absorption of moisture in the rainy season. Overgrown or firm sandy ground was preferable to bare, loose sand; but even the drifting dunes offered them a better choice than the dark humus intermixed with rock. Other requirements of a well-located *ranchería* were: proximity of potable water, a commanding view, the outlying

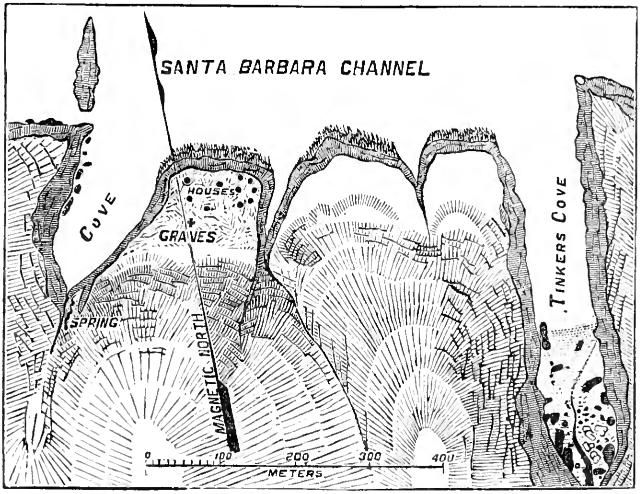


Fig. 1.

rocks bearing eatable mollusks, fish in the adjoining kelpy waters, and game in the neighboring country. Water in small rivulets and springs was preferable to larger streams and rivers, unless these were stocked with fish. A commanding view was subordinate to the condition of the soil and the proximity of water, especially on the islands in Santa Barbara Channel, where no surprising enemy was to be guarded against; there a small boat-landing was one of the main considerations, because the islander's sustenance was mainly derived from

fishing, hunting on the water, and barter with the dwellers on the mainland. To gather shell-fish the aborigines often went long distances, which called into existence temporary camps wherein we hardly find anything but layers of shells and some burned beach-rocks, indicating former fireplaces, scattered in small clusters over their surface. The mollusks, after their shells had been removed, were dried in such temporary camps for easier transportation to distant villages.

But let us examine one of the sites of such aboriginal villages, commonly termed "shell-heaps" or "shell-mounds," bleached shells being by far the larger and more conspicuous part of their remains. I will select one of the many stations which I have investigated for the Smithsonian Institution during recent years. Its location is near a narrow inlet, called Tinker's Cove, on the island of Santa Cruz, one of the group in the Santa Barbara Channel (*see* Fig. 1). It possesses all the requirements of an aboriginal settlement, only the game-ground

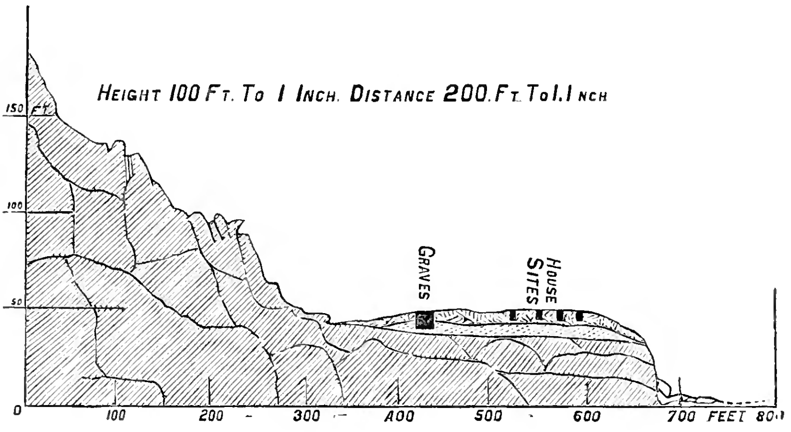


FIG. 2.

is wanting, as no animals save a small gray fox, and several species of land-birds, exist on the islands. The ground upon which the station is located is of a rocky, irregular structure, mostly bare and destitute of vegetation; a cove, affording an excellent boat-landing, adjoins to the westward of it; outlying rocks, of which but few appear in the sketch, are covered with edible shell-fish; a mass of kelp and seaweed grows in the adjoining waters, and is thickly stocked with fish; a spring of potable water is found in the deepest part of the cove. Sand is found only at a distance of between four and five hundred yards to the eastward, in a small hidden beach of the narrow fiord of Tinker's Cove, which is of very difficult access by land, as the sides of the inlet form walls of over one hundred feet in height, and in larger quantities farther away to the westward of the station. It is,

therefore, evident that the layer of sand covering its rocky ground is artificial, and placed there by the aborigines, not a natural deposit accumulated by drifts, etc. The mound begins at the brink of the bluff, some thirty feet above high-water mark, and extends back over a flat of a little more than one hundred yards, toward the ascending hill, diminishing gradually in height, and ceasing entirely before the rocky outcroppings are reached, whence the ground rises rapidly into a ridge, forming a spur of the backbone of the island (*see* Fig. 2). Investigation revealed the artificial formation to consist of a layer of shells, most of which are still found among the living species on the island, bones of fish, sea-fowl, seal, and sea-lions, and whales, dogs and foxes, and a great mass of cobble-stones of all sizes, especially of the size of a fist as used for fireplaces, and chippings of different varieties of chert, chalcedony, jasper, quartz, etc.—rocks suitable for the manufacture of knives, arrow-heads, spear-points, and other cutting tools, which do not occur *in situ* on the island and had to be imported. The whole is mixed with a large quantity of sand, reaching to a depth of about five feet at its deepest part, where formerly the dwellings stood. Underneath the layer of animal remains, the kjökken möddings—kitchen-middens or cooking *débris*—of a former people, pure sand is met in which we find but few valves of an edible shell-fish, or beach-rocks showing marks of fire, or such marks as are made by human hands, and were probably introduced while the dwelling-mound was raised pre-

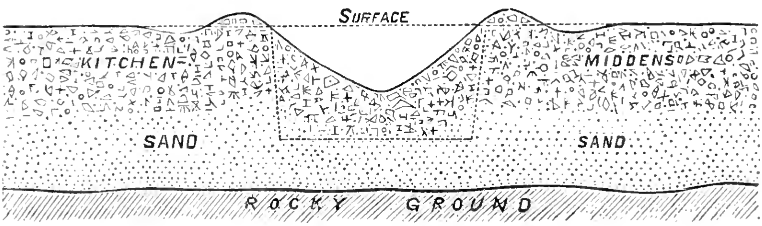


FIG. 3.

paratory to the erection of the hut. The sand—which was either carried there overland, or in canoes from some neighboring sand-bank—attains a depth of about three to four feet, and is deepest around the circular depressions of the house-sites, indicating the embankments which had been raised around the huts. The section, Fig. 3, represents a site of a former dwelling as now found, and its original depth, as indicated by broken lines, may occasionally be traced by still remaining upright boards of the former subterranean inclosure. After the erection of the dwellings, the accumulation of the kjökken möddings began to spread all over the town-site, but was kept imbedded in sand by fresh supplies, thus raising the level of the village gradually, and increasing the depth of the subterranean part of the hut until the latter was deserted, or built over with a new structure.

Near the houses, where in all probability the cooking *débris* had first been deposited, it is now and then found in heaps almost destitute of sand; but, no doubt, after a large quantity had thus been accumulated, it was spread over the ground of the town, evened, and smoothed by layers of sand. The proportion of sand mixed with the cooking *débris* is about one-half the weight of the whole mass. The size of a town-site varies from about 100 metres in length and width, like the one illustrated in the figure, to 1,200 metres, or three-quarters of a mile, in length, and from 100 to 300 metres in width, the extent of *Os-bi*, a *ranchería* in Santa Barbara County, about five miles south of Point Sal, which is the largest shell-mound derived from permanent habitation thus far explored on this coast.

The same features of an aboriginal settlement we observe in Oregon, 1,000 miles to the north. If we take, for instance, the ruined settlement of the *Chetl-e-shin*, situated on the commanding elevation of the north bank, and near the mouth of Pistol River: in front the wide ocean expands, with a number of large outlying rocks; Pistol River washes the base of the bluff upon which the station is situated; its waters are stocked with trout, and, in certain seasons, abundantly with salmon; to the left, or eastward, a mountain-brook empties into the river at the foot of the *ranchería*, and a spring issues between the upper and lower town-sites; back of the coast the country extends in a gradual rise toward a steep and heavily-timbered ridge, beyond which it becomes almost impenetrable, owing to thick forests and their undergrowth, and vines, the safe home of elk and bear. The rocky ground upon which the town was located is covered with a deposit of sand, of which the neighboring beach offers an abundance, and kjökken möddings of great age in its lower layers, with that peculiar mouldy, ash-like appearance, sprinkled with particles of decayed shells, so characteristic of an aboriginal settlement.

It is evident that such a ground, needing artificial foundation for the establishment of a town, was not suitable either for a burying-ground site; we must, therefore, look for the graves of these people within the artificial mounds. There is an exception to this when the ground is naturally sandy, or soft; then we must look for the graves within an easy distance, say about 150 metres, in some prominent place and in sight of the *ranchería*. The graves consist of a pit varying between two and fifteen metres square, and not over two metres in depth, partitioned into smaller spaces by whales' bones and slabs of stone, or by wood. On the islands the gigantic bones of the whale are almost exclusively used; while, on the neighboring mainland, limestone, which splits board-like into slabs, and also whales' bones, and pine and red-wood, are used. Graves of this description have been found in California south of San Francisco, while in Oregon the mode of burial is different, the interment being either made in detached graves, or in houses previously demolished by fire.

SKETCH OF SIR WILLIAM THOMSON.

THIS distinguished physicist and mathematician was born in Belfast, in June, 1824. His father, Dr. James Thomson, was a man of large capacity and culture, who studied in the Glasgow University, became head-master of the Belfast Academical Institution, and in 1832 was appointed Professor of Mathematics in the University of Glasgow. He made various improvements in mathematics, and wrote books upon education. William passed through the Glasgow University early, and then entered St. Peter's College, Cambridge, from which he graduated as second wrangler in 1845, and he was immediately elected Fellow of his college. He afterward went to Paris, and worked in the laboratory of Regnault. In 1846, at the early age of twenty-two, he was appointed Professor of Natural Philosophy in the University of Glasgow, a position which he has filled with distinction, and still occupies.

Sir William Thomson's earliest contributions to physical science were on the subject of heat, the laws of its motions being treated mathematically. A remarkable paper on "The Uniform Motion of Heat in Homogeneous Solid Bodies," written at the age of seventeen, was full of original conceptions, but it was afterward found that Thomson had been anticipated in his ideas by Gauss, Chasles, and George Green, of Nottingham. In 1842 he published an important paper on "The Linear Motion of Heat," which contained a method of deriving geological dates from underground temperatures, a subject which he treated in his inaugural address, in entering upon his professorship at the university.

It will be impossible here to give any account of the numerous contributions to science made by Sir William Thomson, as they were generally of so mathematical a cast as to be unintelligible to ordinary readers. His papers on "Electro-Statics" and on "Magnetism" were collected and published in 1872, in a valuable volume of six hundred pages. The more interesting aspects of his work have been well described by a writer in *Nature*, and we cannot do better than to quote some passages from his notice:

"His electrostatic researches led Thomson to the invention of very beautiful instruments for electrostatic measurement. The subject of electrostatic measurement occupied much of his attention from the very earliest, when he was obliged to call attention to the defects of the electrometers of Snow Harris. His labors in this direction have produced the quadrant electrometer, which is employed for all kinds of electric testing in telegraph construction, and for the registration of atmospheric electricity at Kew Observatory; the portable electrometer, for atmospheric electricity and for other purposes, in which the extreme sensitiveness of the quadrant-electrometer is not required; and the *abso-*

lute electrometer, which serves for reducing the scale-readings of other instruments to absolute measure, and which was used by Thomson in his measurement of the electrostatic force producible by a Daniell's battery and in many other investigations. Those who have seen the collection of electrometers in the Loan Collection at South Kensington will not think it too much to say that to Sir W. Thomson is due our present system of practical electrometry.

"But while thus engaged in investigations in electrostatics and magnetism, there were many other branches of science that were receiving from him advancement in a not less remarkable way. There is no part of his work of higher importance than his investigations on the Dynamical Theory of Heat. These were communicated in a series of papers to the Royal Society of Edinburgh, the first of which was given in 1849. It was a critical account of Carnot's memoir of 1824, 'Réflexions sur la Puissance Motrice du Feu.' Though Rumford and Davy had, in the beginning of this century, experimentally disproved the material theory of heat, their experiments and arguments were unheeded and nearly unknown; and it was only after 1843, when Joule actually determined the dynamical equivalent of heat, that the great truth that heat is a mode of motion was admitted and appreciated. Thus Carnot, although dissatisfied with it, was obliged to adopt the material theory of heat in 1824; and, regarding heat as indestructible, spoke of the letting down of the heat from a higher to a lower temperature, and looked on the production of work by the heat-engine as a phenomenon analogous to that in which water, descending from a higher to a lower level, does work by means of a water-wheel. Thomson, among the first to appreciate the importance of Joule's results, set himself to alter the theory given by Carnot into agreement with the true theory; and in the series of papers referred to, placed the whole science of thermodynamics on a thoroughly scientific basis. In 1846 he first suggested the reckoning of temperature on an absolute thermodynamic scale independent of the properties of any particular substance. Subsequently, in consequence of experimental investigations of the thermodynamic properties of air, and other gases, made in conjunction with Joule, he showed how to define a thermodynamic scale of temperature having the convenient property that air-thermometers and other gas-thermometers agree with it as closely as they agree with one another. This system of reckoning temperature gives great facility for the simple expression of thermodynamic principles and results.

"Having here mentioned Joule and Thomson together, we cannot omit to remark that some of the most admirable researches in thermodynamics were those undertaken in conjunction by these two attached friends.

"Among the many important results of Sir W. Thomson's investigations in thermodynamics, one of the most remarkable was his discovery of the principle of dissipation of energy, announced by him in 1852. During any transformation of energy of one form into energy of another form there is always a certain amount of energy rendered unavailable for further useful application. No known process in Nature is exactly reversible, that is to say, there is no known process by which we can convert a given amount of energy of one form into energy of another form, and then, reversing the process, reconvert the energy of the second form thus obtained into the *original quantity* of energy of the first form. In fact, during any transformation of energy from one form into another, there is always a certain portion of the energy changed into heat in the process of conversion; and the heat thus produced becomes dissipated and diffused by radiation and conduction.

"Consequently, there is a tendency in Nature for all the energy in the universe, of whatever kind it be, gradually to assume the form of heat, and, having done so, to become equally diffused. Now, were all the energy of the universe converted into uniformly-diffused heat, it would cease to be available for producing mechanical effect, since for that purpose we must have a hot *source* and a cooler *condenser.* This gradual degradation of energy is perpetually going on; and sooner or later, unless there be some restorative power, of which we at present have no knowledge whatever, the present state of things must come to an end.

"In 1854 Faraday, with an experimental cable, investigated the cause of the *retardation of signals* first observed in the working of the cable between Harwich and the Hague. Thomson, taking up the question, published an investigation of the nature of the phenomenon, one practical result of which was that with cables similar in lateral dimensions the retardations are proportional to the *squares of the lengths.* This law is now commonly referred to as the 'law of squares.' About this time it was proposed to construct a cable to connect England with America; and it became obvious that the discovery of the retardation of signals raised a question whether the transatlantic cable would not prove a commercial failure. Whitehouse, experimenting with 1,125 miles of cable, found the transmission of an instantaneous signal to the farther end of the cable to occupy one second and a half. The length of a cable required to connect Ireland with Newfoundland is twice that of the experimental cable of Whitehouse; and thus, according to the law of squares, the time taken to transmit an instantaneous signal through a cable similar in lateral dimensions to that of Whitehouse, and joining those two places, would be no less than *six seconds.* In 1856 Whitehouse read a paper before the British Association, in which he described experiments by which he hoped to disprove the law of squares. Thomson replied in the *Athenæum* (November 1, 1856); and subsequent experiments have established the correctness of his law.

"Fortunately a true understanding of the nature of the phenomenon of retardation led Prof. Thomson to the method of overcoming the difficulties presented. The disturbance produced at the extremity of a long submarine cable by the application for an instant of electromotive force at the other end is not, as in the case of a signal through an overhead land-line, a pulse, practically infinitely short, and received only a minute fraction of a second after it was communicated. Instead of this, a long wave is observed at the farther extremity, gradually swelling in intensity, and as gradually dying away. Its duration for such a cable as we have been speaking of would be the whole six seconds, calculated from the experiments of Whitehouse. Prof. Thomson perceived that an instrument was required which should give an indication of a signal received long before the wave has acquired its maximum intensity, and in which the subsequent rising to maximum intensity should not render unreadable a fresh signal sent quickly after the previous one. This was effected by his 'mirror galvanometer;' and it was by means of it that the messages transmitted through the 1858 Atlantic cable were read.

"The 1858 cable, submerged under difficulties that many times threatened to be insurmountable, soon failed. Several important messages were, however, transmitted through it; and it served to *prove* the feasibility of the project which many eminent engineers up till that time regarded as chimerical. Before another attempt was made the labors of Prof. Thomson and others, to all of whom the world owes a deep debt of gratitude, had so improved the construc-

tion of the cables and the mechanical arrangements for submersion, that though many difficulties presented themselves they were all, in 1866, triumphantly overcome. It was on his return from the submersion of the 1866 cable, and the raising and the completion of the 1865 cable, that the honor of knighthood was conferred on him along with others of his distinguished fellow-workers.

"Recently Sir William Thomson has invented a new and very beautiful instrument, the 'siphon recorder,' for recording signals on long submarine lines. It is in use at all the telegraph-stations along the submarine line connecting England with India. It is also used on the French Atlantic Cable, and on the direct United States line. Sir W. Thomson, Mr. Varley, and Prof. Jenkin, combining their inventions together, have given the only system by which submarine telegraphy on long lines has been carried on up to the present time.

"Sir William Thomson is an enthusiastic yachtsman and a skillful navigator. His recently-published popular lecture on 'Navigation' proves this; and, with that bright genius which enriches all with which it comes in contact, his improvements in navigation are of very high importance. The general adoption of Sumner's method, now made simple for the navigator, would be a reform in navigation almost amounting to a revolution, and is one most highly to be desired. Sir William Thomson has also invented a new form of mariner's compass of exquisite construction. It possesses many advantages over the best of those in general use, not excluding the Standard Admiralty Compass; but its special feature is that it permits of the *practical* application of Sir George Airy's method of correcting compasses for the permanent and temporary magnetism of iron ships. He has also invented an apparatus for deep-sea sounding by piano-forte wire. This apparatus is so simple and easily managed that he has brought up 'bottom' from a depth of nearly three nautical miles, sounding from his own yacht, without aid of steam or any of the ordinary requisites for such depths. His method was much employed in taking rapid soundings during the laying of telegraph-cables along the Brazilian coast to the West Indies. It has also been used with great success on the United States Submarine Survey. Recently, while on his way to Philadelphia, Sir W. Thomson himself was able to take flying soundings, reaching the bottom in sixty-eight fathoms, from a Cunard Line steamship going at full speed.

"Sir William Thomson is a Fellow of the Royal Society of London and of the Royal Society of Edinburgh. He has received the Royal Medal of the former and the Keith Medal of the latter. He is also an honorary member of several foreign societies. The Universities of Dublin, of Cambridge, and of Edinburgh, have each conferred upon him the honorary degree of LL. D., and that of Oxford the honorary degree of D. C. L. On his marriage in 1852 he gave up his fellowship at St. Peter's College, Cambridge; but in 1871 his college again elected him to a fellowship, which he now holds."

CORRESPONDENCE.

INSECTS AND FLOWERS IN COLORADO.

To the Editor of the Popular Science Monthly.

IN my paper on "The Fertilization of Flowers by Insect Agency" ("Proceedings of the American Association for the Advancement of Science," 1875, pp. 244, 245), I say: "On my first visit to the Rocky Mountain region, the absence of insects proved very annoying to the entomologists who accompanied me. Indeed, the paucity of animal life of all kinds in the Rocky Mountains is well known; but there is no more scarcity of seed in the colored flowering plants than in similar ones elsewhere." At the conclusion of my address, Prof. Riley objected to the accuracy of this statement—not from his own personal experience, as I believe, and from overlooking, as I supposed, that I was referring to insects relating to the cross-fertilization of flowers—chiefly *Hymenoptera* and *Lepidoptera*. Mr. Charles R. Dodge, editor of *Field and Forest*, was one of the entomologists I referred to. In vol. i., No. 12, page 89, he describes that expedition in the summer of 1871: "The route carried us through Golden City and Idaho Springs to South Park, thence to Pike's Peak and the Garden of the Gods, where we emerged from the mountains and returned to Denver over the level plateau known as the 'Divide;' and, from the time we passed the foot-hills near Golden City, and entered the first cañon in the mountains, we were struck with the comparative paucity of the insect fauna. . . . In the mountains, the marked *absence* of insect-life in variety, except in favorable localities, was the rule, and not the exception." Traveling was not so easy then as now, and I think it took us nearly three weeks. The party comprised thirty persons, all of whom were interested in aiding the collectors. Mr. Dodge sums up his remarks by especially noting that "the entire mountain-trip yielded so small a number of nocturnal *Lepidoptera* that they are hardly worth mentioning." He adds, "I have conversed with a few other entomologists on this subject, and they agree with me perfectly."

Now, if we turn to Hayden's "Report of the Survey of Colorado," for 1873, we find Lieutenant Carpenter substantially recording the same thing. Here are the doings of a whole season, and not for three weeks merely, and only five species of butterflies are found; and, indeed, he remarks that "*Lepidoptera* are undoubtedly peculiar to high latitudes and great elevations." This leaves us with scarcely anything but bees to do the whole work of flower-fertilization in the Rocky Mountain region. But even these seem to be confined to some considerable elevation. In an expedition in 1873 I saw *Bombus termarius* in abundance, but on no other flowers than *Polygonum bistorta*, on Gray's Peak, on the flats near the timber-line. I was struck by the fact that they seemed to visit only this species, evidently getting all they required from it, and neglecting everything else. I did not see bees anywhere in our expedition of 1871 in lower altitudes, nor do I think there were any in 1873, except in this high region near the timber-line. Of course, there might have been, but, if so, they were so scarce as to attract little attention. This seems to have been the experience of Lieutenant Carpenter. He says, "The humble-bee was always to be seen in midsummer at the verge of the Alpine flora, busily engaged in collecting its store of pollen from the few flowers to be found." This does not certainly say they might not be found lower down, but it is a fair inference. My collections in this district embraced over seven hundred species of flowering plants and ferns. I can say that among these were quite as large a proportion of colored flowers as in an equal number gathered East, where insects are conceded to be numerous.

But just here Prof. Gray steps in with the following note: "*À propos* to Mr. Meehan's suggestion that, although the Alpine plants of the Colorado Rocky Mountains are mostly high colored, insects are there so rare that they can be of no material aid to fertilization, and therefore these plants

must self-fertilize, it may not be amiss to introduce testimony. An entomologist now at my side, who has passed four summers among these mountains, and made frequent visits to the Alpine regions, informs me that 'he has always found insects of all orders quite abundant in the Rocky Mountains'" (*Silliman's Journal*, 1876, pp. 397, 398). The route which I have described can hardly be called the "Alpine" region, unless it be in so far as it relates to Pike's Peak, which, however, I did not join my companions in ascending, having chosen in preference to explore alone what was then an unknown cañon, and which I named after my good friend Dr. Engelmann, whose name it still bears. There is nothing in my paper, as referred to by Prof. Asa Gray, to warrant the statement that I was confining myself to "Alpine" regions. Indeed, the "suggestion," so far as it relates to the paucity of insects, should refer to the "entomologists who accompanied me," and not to myself. All I claim is that the "entomologists" found no insects, while I found colored flowers seeding abundantly.

In view of the testimony of the entomologist at Dr. Asa Gray's side, that insects of all orders are quite abundant in the Rocky Mountains, I should be glad to have, through The Popular Science Monthly, a list of the *Hymenoptera* and *Lepidoptera* that are abundant enough, in the particular part of the Rocky Mountain region covered by my experience, to probably act as cross-fertilizers of flowers, noting those which may perhaps be introduced since 1871, as it is well known that, with the introduction of agriculture and horticulture, insects often follow.

I do not suppose that, in the large number of observations I have placed on record, there will not be now and then one found "imperfect." Not one of us who are working in this field but, with all our care, must expect such annoyances. As the relation of insects to plants in the flora of Colorado is an important one, and I never heard the view I have taken of it questioned except as now stated, I think it important to science to know exactly how far my statement is imperfect, if imperfect at all. Thomas Meehan.

Germantown, Pa., *November* 27, 1876.

THOMAS CARLYLE AND THE DARWINS.

To the Editor of the Popular Science Monthly.

There are floating in the American press some ill-natured remarks of the octogenarian, Carlyle, that merit a little attention. The remarks reported are as follows: "I have known three generations of the Darwins—grandfather, father, and son: atheists all. . . . I saw the naturalist not many months ago; I told him that I had read his 'Origin of Species' and other books; that he had by no means satisfied me that men were descended from monkeys, but had gone far toward persuading me that he and his so-called scientific brethren had brought the present generation of Englishmen very near to monkeys. A good sort of a man is this Darwin, and well-meaning, but with very little intellect."

Remark 1. If a "very little intellect" can change the present generation of Englishmen to monkeys, what are those Englishmen made of?

Remark 2. Carlyle has known the three generations of the Darwins, beginning with the grandfather. Erasmus Darwin, the grandfather, died in 1802, about six or seven years after Carlyle was born! Is it exactly the right thing for the old gentleman to say he knew him?

Remark 3. "They are atheists all." Now, two years before Mr. Carlyle was born, to wit, 1794, the grandfather, Erasmus Darwin, published the great work of his life, "The Zoönomia, or Laws of Organic Life," and on the first page he says: "The great Creator of all things has infinitely diversified the works of his hands, but has, at the same time, stamped a certain similitude on the features of Nature, that demonstrates to us that *the whole is one family of one parent*." And, on page 77, he says expressly: "I do not wish to dispute about words, and am ready to allow . . . and to believe that the ultimate cause of all motion is immaterial, that is, God." Mr. Carlyle may be a well-meaning man, but his knowledge of that grandfather, although at the ripe age of six years, must have been rather imperfect.

But the charge of atheism includes the naturalist, Charles Darwin. The candid readers of Charles Darwin's works know better. Many people, on reading the books of Genesis and Job, grow skeptical; but no

one who reads the marvelous revelations of the works of God which this learned naturalist has published can for a moment doubt the existence of the divine wisdom which pervades the realms of Nature.

R. M. K. Ormsby.

Chester Hill, N. Y., *November* 27, 1876.

To the Editor of the Popular Science Monthly.

Dear Sir: In a letter addressed to you, and published in your columns, from the pen of Thomas Meehan, Esq., in which he is "getting right on the record," I am disturbed by the following expression in reference to my Buffalo address: "Prof. Morse could only help me with the audience by remarking, 'We all know that Mr. Meehan is a Darwinian, and an evolutionist, but must say he has an odd way of putting it.' That my good friend does not regard me as much of either is, however, clear, from his making no reference to any of my labors in his 'History of Evolution.'"

The reader of this might think that I had either overlooked the interesting contributions of Mr. Meehan in the "Proceedings" of the Philadelphia Academy, and his own journal, or else had done him a manifest injustice. That I am not guilty, either of oversight or injustice in this matter, the following lines from my Buffalo address will prove: "A review of the work accomplished by American students, bearing upon the doctrine of descent, must of necessity be brief. Even a review of a moiety of the work is beyond the limits of an address of this nature. *And for obvious reasons I must needs here restrict it to one branch of biology, namely, zoölogy.*" The *obvious reason* is that I am not a botanist, therefore no reference is made to the works of Dr. Gray, Mr. Meehan, Prof. Beal, and others, who have made valuable contributions to the subject. In the solitary case where I alluded to the fertilization of yucca, it was to show the curious moth *Pronuba*, so admirably described by Prof. Riley, as an insect showing peculiar adaptations for the work in hand.

Edward S. Morse.

Salem, Massachusetts, *November* 4, 1876.

EDITOR'S TABLE.

PHILANTHROPIC FANATICISM AGAINST SCIENCE.

REFERENCE has been repeatedly made in our pages to an English Parliamentary Commission, appointed to inquire into the practice of vivisection, or experiments upon living animals, made for scientific purposes by the physiologists of that country. The inquiry was the consequence of a prolonged and intense public agitation, in which the sympathies of the people were excited, and their indignation aroused, by frightful stories of cruelty deliberately and wantonly perpetrated upon innocent animals under the pretext of advancing scientific knowledge. The movement was systematically and skillfully engineered by those who make philanthropy a business. Money was plentifully contributed by the rich to carry it on, and with plenty of money there is never any difficulty in engaging the press in a good work. Appealing to the sensibilities by exaggerated accounts of the way poor animals were tortured, the subject naturally took a deep hold of the sympathies of women, and its measures were promoted and sustained by many ladies of wealth and high social position, and were understood to be warmly encouraged by the queen herself. But the humane feelings of both sexes were profoundly stirred by the tales of atrocity that were circulated, so that the scientific physiologists of the country began to be looked upon as fiends, reveling in the infliction of agony upon helpless animals. The stories, of course, were unscrupulous exaggerations, or arrant lies, but the public is a great believer and fond of pungent sensations, while fervid philanthropy is not apt to trouble itself much about cool matters of evidence.

The Parliamentary Commission, con-

stituted of both the enemies and the friends of vivisection, at length took the matter up, and, as is customary with English commissions, it made a thorough investigation. Witnesses on both sides gave voluminous testimony on all aspects of the subject, and after patient and impartial consideration the body made a report which was designed to be preliminary to legislation upon the question. As regards the merits of the controversy, it was agreed that vivisection, or operations upon living animals, is a necessary and a proper thing, and, as practised by scientific men, has been of great use to the world. The commission, moreover, entirely acquitted the physiologists of the charge of cruelty. It commended the humanity of the medical profession in England, and testified that medical students were extremely sensitive in regard to the infliction of pain on animals.

One would think that with this decisive expression on the general subject, and with this complete vindication of the aspersed parties, the agitators would have been rebuked, and the case at once dismissed. But the anti-vivisection movement was quite too formidable to allow of this. That hysterical rampage of British philanthropy was strong enough to coerce the Government against its own protestations, and to extort from it a law that was alike an insult to science and a disgrace to the country. The physiologists were expressly acquitted of all improper practices when left free as they had always been to pursue inquiries in their own way, and they were then handed over to the future control of the police. They were vindicated from all imputation of cruelty, and then subjected to the operation of a statute against cruelty to animals. Though their experiments had for their object the ultimate mitigation of pain to the higher creatures most susceptible of pain—though their investigations were of so beneficent an influence that, as Prof. Tyndall justly says, "no greater calamity could befall the human race than the stoppage of experiments in this direction"—yet the physiologists were classed by law with those cold-blooded brutes who cruelly overdrive, abuse, and torture domestic animals. Though the necessity, and form, and extent of his experiments on animals were, in the nature of the case, matters of which the operator alone could judge, as their essential object is the elucidation of undetermined problems, yet it was legislated that he should not pursue his work except by a license from a political office-holder, and the making of any experiment calculated to give pain to an animal was declared an offense punishable in the first instance by fine, and in the second by fine and imprisonment, unless certain conditions were complied with to the satisfaction of the said political functionary who was put in control of the whole business. In short, legislative wisdom, stimulated by philanthropic zeal, outlawed vivisection as a crime, and then provided for its perpetration by leave of the Secretary of State.

Let us now see how much there was of real philanthropy or of hearty sympathy for the sufferings of the lower animals at the bottom of this movement. Had it been sincere, or based upon principle, it would have undoubtedly aimed to be effectual, and to have inflicted the penalties for cruelty alike upon all delinquents. But the law was so framed as to bear hard only upon the poor, and to give a virtual license to the rich, who could easily pay the fines prescribed for inflicting whatever cruelties they chose. Again, the law passed was intended, by the terms of its title, to prevent "cruelty to animals;" but a clause was quietly introduced at the end limiting it to the protection of *domestic* animals only — a clause which stultified the enactment, and showed the emptiness of its purpose by exposing immensely the greater portion of the inferior animate cre-

ation to all the wantonness of torture; and not only that, but to tortures that were sure to be inflicted, and were provided for by the limitations of the statute. Of the sufferings to which certain of the lower animals are subjected by the favorite English pastime of hunting them with hounds, which is freely permitted by law, we do not speak, but will only refer to some facts regarding the universal English sport of "shooting." It is well known that the British Parliament generally adjourns about the time that the partridges and grouse cease to be protected by the game-laws of the country; and no one who knows anything of the strength of British instincts for destructive field-sports will consider the connection, in this case, as altogether fortuitous. Lords, Commoners, and everybody that can afford it, then seize their guns, and betake themselves to the fields and mountains wherever there is anything to be killed. It is the fashionable and the national thing. Those who own grounds range over them with their guests in quest of beasts and birds, and others hire the privilege of doing it for longer or shorter times. The whole matter is legally regulated. Licenses are issued to keep guns, and licenses to kill game. A few of all the multitudes who enter upon the sport are good shots, and kill a large portion of the creatures fired at. But the most of them are bad shots, and wound many more than they kill. When hit, if not captured, they escape with their bodies penetrated with leaden pellets—some of them to die; some to suffer miserably; and others to recover after experiencing various degrees of pain. A writer in *Nature* has gone into the statistics of shooting, with a view to estimate the probable numbers of creatures that thus suffer by wounding. He adopts as his basis the number of those who take out licenses, the duration of the season, and the days given to sport, and, by reckoning the number wounded per day that are not killed, he arrives at a proximate conclusion regarding the aggregate of animals that yearly suffer from this cause. The number of licenses issued is taken from government reports, which indicate, for example, that in the year 1873–'74 there were 132,036 holders of gun-licenses, and 65,846 holders of licenses to kill game. Assuming that each sportsman wounds three head of game per day, which are not taken, he finds that the total number of animals upon which pain is thus inflicted amounts to many millions annually. We cannot go into the details of his calculation, which is carefully and fairly made out, but will quote the concluding passage of his article:

"If we may trust our figures, here are the plain facts that acute pain of uncertain duration was, in the year ending March 31, 1874, inflicted upon *over twenty-two million* animals, and in the following year upon *over twenty-three million and a half*, in the British Islands. We are not aware that we possess any bias that would make us exaggerate our estimates to produce these results. Our only object is to attempt as near an approximation to the truth as we can. The figures stand for themselves, and if any one thinks he can furnish fairer averages let him give his data for them. We are, as it is, willing to guard against any unconscious exaggeration, and to knock off more than ten per cent. of our grand totals, so as to say roundly that only twenty millions have suffered in each year. But we would invite our readers to reflect on the proportion which even that number bears to the number of animals which during the same time have been subjected to experiment by the physiologists of this country. The latter have been by many excellent persons held up to obloquy as monsters of cruelty. If this has been done justly, what must they think of those who use the gun?"

From the point of view here presented, the state of the case has been pithily summed up by Mr. Lowe, in a recent able article in the *Contemporary Review*:

"According to present British law, as revised under the spur of the latest philanthropy, it appears that, while the man of

science must not inflict the least pain on any animal for the most beneficent object, any one else may inflict the most exquisite tortures on any non-domestic animal—that is, on ninety-nine hundredths of the brute creation—without any punishment at all. If he can show that the torture was inflicted from cruelty, from gluttony, for money, for amusement—for any motive, in fact, except a desire to do good by extending knowledge—he enjoys the most perfect impunity; but woe to him if in his infliction of pain there is any alloy of science!"

An attempt was made to protect animals from pain against the sportsman as well as the man of science, by putting both upon the same footing as regards penalties, but it failed. Mr. Lowe says:

"A motion to extend the law which forbade the cruelly abusing or torturing any domestic animal, to animals non-domestic, and to increase the penalty to a level with the penalty imposed for performing a painful experiment, was lost by a large majority, the Government voting against it. . . . The efforts, therefore, of the two Houses of Parliament to introduce humanity into our laws, as regards animals, stands thus:

"1. Absolute liberty to torture all non-domestic animals except by way of scientific experiment.

"2. Practical liberty for any one who can afford to pay five pounds to torture domestic animals except by way of scientific experiment.

"3. No punishment for painful experiment except by leave of the Secretary of State."

Now, politicians are not partial to science, but the British Government would never have committed itself to such ridiculous legislation except for the pressure of a fanatical agitation which grew out of no real sympathy with the sufferings of the lower animals. Had it been so, the crusade would have been directed against sportsmen for their extensive and selfish infliction of cruelty, rather than against the physiologists for the small amount of pain which they caused, and that, too, in the unselfish and beneficent pursuit of knowledge which is designed to mitigate human suffering and save human life. The agitation was incited by fictitious horrors, and was worked up and sustained in a business way by practised manipulators of popular passion and prejudice. It was directed against a certain class of scientific men, and had its chief root in those narrow prejudices against science which the press and the pulpit have recently done so much to nourish and sustain. There has been an especial dread of biological science, because it meddles with the mysteries of life, and aims to explain things which ignorance and superstition would rather not have explained. Experiments upon animals are looked upon with abhorrence, not solely because of the creatures' suffering, but also because the knowledge thus deduced and applied to man is held to be derogatory and degrading to his nobler nature. The anti-vivisection movement, in short, was very much a result of that feeling of jealousy and hostility toward science which is by no means confined to the ignorant classes, and which it was not difficult to inflame into the fanatical intensity of an aggressive and intolerant popular movement.

POLITICAL ECONOMY IN THE UNITED STATES.

The hundredth anniversary of Adam Smith's "Wealth of Nations" has been the occasion in England of a pretty careful review of the science which he founded—its methods, its province, its achievements, and its prospect of future usefulness—with the result, not of reaching definite conclusions, but of revealing very wide differences of opinion as to what political economy really is. The general tone of the discussion is decidedly doleful; dissatisfaction with the present and doubt as to the future being the only points upon which there is unanimity. Politicians and newspapers alike declare that the centennial marks the decline and not the consummation of the "dismal science;"

that the points of the present controversies are not of the same importance as those of earlier days; that there remains not much to be done in the way of direct legislation; in short, that its great work is done.

In a sense this may be said to be true. The repeal of usury and corn laws, and the establishment of free trade, *was* a great work; and in many minds this practical application of principles stood for the science. Being accomplished, it forms so essential a part of the commercial policy of the country, and has become so rooted in the minds of the present generation, that the value of the benefits derived is not duly appreciated, nor the importance of extending this work to other countries sufficiently recognized.

Economical reform in England has reached that critical period, which comes in the history of all reforms, when effort has been crowned with success. Its old rallying-cries have lost their potency because the ideas which they represented have become universally-accepted axioms; the evils which it labored to correct no longer exist; its champions find their old weapons useless, and no new ones are, as yet, fitted to their hands.

Naturally, this chaotic condition has begotten dissension and revolt, even among those who are by no means willing to admit that the functions of the science have become unimportant; the ranks of the faithful have fallen into disorder; rival sects have arisen, and the validity of time-honored tenets is discussed with earnestness if not with heat. The orthodox school still holds in the main to the old creed; while the dissenters, styling themselves the Historical School—a name the fitness whereof their opponents decline to allow—denounce this creed as being based upon rude generalizations, obtained by a superficial and unphilosophical process of abstraction.

We shall not, at this time, attempt any discussion of these questions. We have faith in political economy as a science, and a perfect assurance that, whatever subdivision or specialization it may undergo, its vitality will remain unimpaired. We could, therefore, look upon the present contention with equanimity were it not for the reflection that, here in America, we are still disputing over those economical principles which in England are irrevocably settled.

However true the statements that the science has outlived its usefulness may be with regard to that nation, they have no application to the condition of the United States. Here its most fundamental propositions are matters for discussion and legislation, and the problems involved imperatively demand solution. We who, this year, are celebrating the hundredth anniversary, not of a book, but of the nation's birth, have still to decide whether the progress over which we are prone, rightly enough, to indulge in a good deal of self-glorification, has been helped or hindered by the policy of protection which has ruled hitherto; whether, had an opposite course been pursued, our internal resources might not have been quite as fully developed, and at the same time our external commerce have received a commensurate impetus instead of being at its present low ebb. This, and the condition of our currency, are very real questions with us; the way in which they are answered may make all the difference between continued progress and comparative immobility; and yet, while the country is in a ferment from shore to shore over the most inconsequential of elections, these important matters lie apparently dead in the public mind.

The profound stagnation of the commercial world has brought us nearly to a stand. Old combinations are disturbed and broken up. In the lull some of the hallucinations of speculative fever are disappearing, but the

state of our finances is notoriously unsatisfactory, and that which Mr. Lowe is pleased to call the "great work" of political economy, the establishment of free-trade principles, with us remains undone. Is it not time seriously to consider what can be done to make the readjustment of the social elements a favorable one for us—one more adequate to the exigencies of the time?

Prolonged immunity from wars, the sway of sound commercial doctrines, the absence of the element of uncertainty in her finances, has enabled England to absorb a great part of the exchange business of the world. Continental disturbances made her opportunity, and she was ready to improve it. London is a vast clearing-house, while the United States do not act as middle-man between any two nations.

It is almost universally admitted that there can be no peaceful settlement of the Eastern question which can be lasting. Sooner or later it must be submitted to the arbitrament of war, and when that comes England cannot stand aloof. Engaged in such a struggle, she can no longer offer so secure a refuge as formerly to capital seeking a place of safety and stability. She must relinquish, in part at least, this function, and there is nothing mercenary in the suggestion that that would be our opportunity. But, however favorable for our aggrandizement foreign complications might become, they would now find us unprepared to take our rightful place in the world's commerce—unable to arrest the hour. Economical reform is an essential preliminary to success in such an endeavor. Our distance from Old-World centres finds compensation in our freedom from European entanglements; but the obstacles presented by a cumbrous and oppressive tariff, and a depreciated, fluctuating currency—compared with which three thousand miles of ocean are as nothing—would be simply insurmountable. And what is the prospect of their removal?

The answer which must be given is not satisfactory.

There is reason to believe that the vagaries of inflationists are giving place to sounder financial views. There is warrant for the hope that the friends of free trade are increasing in numbers, and that its principles are slowly gaining ground, but no demonstration of this by legislation has yet appeared—nor are there any signs of it. Neither set of politicians seems to consider them worthy of consideration. Meantime the forces of protection are in close order, well appointed and alert—they will make a stout fight, and that there should, at this critical period, be a disaffection anywhere in the ranks of sound political economy, must be regarded as a matter of the gravest concern.

PROFESSOR MARTIN ON SCIENTIFIC EDUCATION.

Lady Burdett Coutts, who, having much money to give away, patronizes numerous charities and receives great applause, has come to be a kind of authority in the sphere of philanthropy, duty, ethics, etc. Hearing much said against science, on account of the experimental study of animals, she sought Prof. Tyndall, to inform him that science was growing *immoral*, because it did not formerly do such dreadful things as it is in the habit of doing now. Prof. Tyndall replied that it was rather growing *biological*, or passing into a new sphere to explore the laws of life, to which experimental investigations on organisms *in life* are indispensable.

This comparatively new subject, biology, which, after three centuries of preparation in physics and chemistry, has only been fully reached by the scientific mind of the world during the last fifty years, is now beginning to be recognized in its full import in our system of higher education. Biological chairs have been founded, and laboratories and schools of biological research

have been established in connection with various of the old European universities; and although we, in this country, have had chairs, and schools, and museums of natural history, connected with our colleges, or apart from them, yet the provision made for biological study in the organization of the Johns Hopkins University at Baltimore marks a decisive step forward in the educational treatment of this important subject.

We give our readers the able inaugural address of Prof. Martin in entering upon his work at Baltimore, and they will be repaid by a careful perusal of it. The statement of principles, purposes, and plans, is excellent; and if they are carried out intelligently and perseveringly, as there is no reason to doubt they will be, the results cannot fail to be in a high degree advantageous. The proposed mode of combining original work with practical teaching is full of promise. Prof. Martin dispels the erroneous and injurious notion, too current, that original work means great discoveries. He points out how students of but ordinary capacity may yet do something to extend the boundaries of knowledge, while at the same time the important ends will be secured of mastering the true methods of inquiry, of making solid acquisitions, and of being able to teach from an actual understanding of the subject. What he says of the influence of scientific study, when conducted by proper methods, and in its genuine spirit, in cultivating the love of strict truth, and the mental habit of seeking it as the supreme thing, deserves the most serious attention. How to include a thorough discipline in truth-seeking, in our systems of education, is the problem of problems yet to be solved. No one who goes to church, or drops into the court-room, or visits our halls of legislation, or reads the newspapers, can fail to see that, with all their learning and volubility, our cultivated men are still very much in Pilate's state of mind in regard to truth. It may not be possible for all educated people to get the benefits of biological training as a part of culture, but the most salutary results will come from making scientific training an integral and established part of higher education. When thorough scientific culture once gets a fair foothold in our colleges and universities, so that its results can be compared with the purely literary training that now prevails, its influence will soon be felt, and we may safely leave the rival methods to the operation of natural selection. Meantime, our teachers will do well to consider carefully Prof. Martin's suggestions, and set themselves to the inquiry, how far it may be in their power to make application of them, in modified ways, in their own sphere of activity.

PROFESSOR HUXLEY ON THE HORSE.

We publish this month the third lecture of Prof. Huxley, as corrected by himself for The Popular Science Monthly, and accurately illustrated under the supervision of Prof. Marsh, of New Haven. The lecture deals mainly with the genealogy of the horse as traced far back into geological antiquity, by the discovery of successive fossil forms in successive strata or deposits. These forms are so closely related, and exhibit so graduated a series of modifications, as to establish the fact of a genetic and derivative relation from the lowest to the highest. The fossil terms of this series were already so far made out in Europe as to satisfy paleontologists there that the pedigree of the horse is established; but, by recent discoveries on this continent, the ancestral chain has been traced still farther back, so as greatly to strengthen the conclusion reached by foreign investigators. To the three ancestral forms found in Europe, which go back to what the geologists call the *Miocene*, Prof. Marsh had added two others, car-

rying the line back to the Eocene formations, and connecting the present Equus or horse-tribe with an early Eocene animal known as the *Orohippus*. In his lecture Prof. Huxley traced the relationship of these six ancestral forms of the existing horse, and based his argument for the demonstrative evidence of evolution on the continuity and extent of the series. But he went further, and stated what the characteristics of a still earlier form would be if it were ever discovered; and, within a month from his departure from the country, Prof. Marsh announces that fossils of the predicted animal have been actually found in the lowest Tertiary deposits of the West, giving the *Eohippus* as the seventh term of paleontological ancestry of the Equine group.

We pointed out last month that proof is a thing of degrees, and that demonstration may be cumulative; and the very case we were considering now furnishes further illustration of it. Prof. Huxley says that the doctrine of evolution and the Copernican theory of the motions of the heavenly bodies have precisely the same basis, that is, "the coincidence of observed facts with theoretical requirements;" and that "an inductive hypothesis is said to be demonstrated when the facts are shown to be in entire accordance with it." But the demonstration becomes still stronger when the requirements of theory lead to the prediction of what must follow from it, and Nature subsequently furnishes the facts that vindicate the prophecy. It is one of the highest tests of the truth of a theory, that it leads to new discoveries, as was conspicuously the case with the wave-theory of light. A scientific professor is reported to have said that the proof of the evolution theory is far less strong than that of the undulatory theory, while nobody regards *that* as demonstrated. On the contrary, it *is* so regarded, and with abundant reason. The objective existence of the ether may not be proved, but this conception is not essential to the theory, and is held by many as nothing more than a convenient assumption or hypothetical artifice to aid the imagination in picturing wave-actions. The essence of the theory, whether the medium assumed be ethereal or material, is that light originates in some kind of undulatory motion, and a rational optical science is now only possible on this view. In the sense in which Huxley uses the term demonstration, as "the coincidence of observed facts with theoretical requirements," it is an established demonstration, and evolution stands exactly on the same ground. The facts are what the theory requires them to be, and what it predicts them to be; it explains them by the operations of real causes, and offers the only explanation we can have without going outside of Nature to get it.

Prof. Huxley has done us great service by going over the question of evidence in his three lectures, and bringing out the full force of the proof for this doctrine, and to make any less claim than he has made is to be wanting in fidelity to the truth.

And from this point of view we must think that Prof. Martin, in his admirable introductory discourse, did not fairly represent the case in giving the scientific status of the principles of the conservation of energy and of natural selection. He said: "These ideas *may or may not* be true; increase of knowledge may confirm or may *possibly* upset them." So sharp an alternative as true or false, determinable only in a contingency of the future, certainly does injustice to the logical validity of these great ideas. They can no more be subverted or abandoned in the future than any other truths of experiment and observation. They may disappear by absorption into larger truths, may change aspects, but they are basal and permanent factors of science, and we see not why the professors

of physics and mathematics might not open their courses by conceding the insecurity of the fundamental principles of their sciences with just as much propriety as the professor of biology.

COMMERCIAL MANIAS.

RECENT writers upon the subject of commercial manias usually indulge in congratulations over the fact that the world is grown more wise; that the mental aberrations of our day are less marked than those of earlier times; that, for example, the absurd Dutch tulip-mania, Law's wild Mississippi scheme in France, and the South-Sea bubble in England, find no parallel in these days of greater intelligence and self-control; that the time has gone by when a sharper could clear $10,000 in five hours by selling shares in "a company for carrying on an undertaking of great advantage, but nobody to know what it is!"

It is probably true that our tendencies are not quite so rabid as those of our fathers, but we hold on bravely to some of their worst follies. It was only at the last session of Congress that the advocates of an unlimited issue of irredeemable paper were strong enough to prevent any steps being taken toward resumption. It was but the other day that the progressive Commonwealth of Massachusetts chose as a representative B. F. Butler, who declares that the "progressive" dollar is a paper dollar so issued that it can never be redeemed. The absorbing interest of a presidential election has hushed somewhat the clamor for the interconvertible note scheme—which is to pay all debts, public and private, and make everybody easy without costing anybody anything—but, had all those who still fully sympathize with the financial imbecility of Mr. Peter Cooper voted for him, the old gentleman would have had a very different showing in the official count. Nor are there lacking concrete examples of credulity which rival any of the exhibitions of former generations. A case in point is now running its course in Spain.

A woman has opened a bank in Madrid for deposits in sums of a hundred dollars and upward, on which she pays interest as follows: twenty per cent. on receiving the deposit, twenty per cent. at the end of the first, second, and third months, and then at the expiration of the fourth month, when eighty per cent. has been already paid, she reimburses the entire sum lent. The payments thus far have been regularly made, and the public are flocking in crowds with their money, the deposits now amounting to several millions of francs. The bankers and savings-banks are being drained of their deposits by this extraordinary traffic. Hours before the bank opens in the morning hundreds of depositors collect, and the presence of the police is necessary to preserve order. In this case "nobody is to know" how the money is employed, and on that point contrary rumors prevail; some assert that the capital is used in working mines of fabulous wealth; others, that the woman is an agent of the Government, adding that it is thus procuring money on more advantageous terms than with its regular bankers! The true explanation will not be long withheld, unless the police interfere to prevent her running off with her plunder. This is almost a precise repetition of a case which took place in enlightened Germany four years ago—the Spitzeder affair of Munich. In this case enormous sums were confided to a woman banker, who lived in opulence, squandering the money of her depositors, and, as she could not repay them, she was sentenced to three years' imprisonment. Her time expired some months ago, and the likeness of the transactions at Madrid to her operations at Munich is strong enough to suggest a common origin.

These cases appear still more re-

markable when we recall the fact that in Continental Europe the confidence in banks of deposit has never attained the strength that it has in this country and in England. Outside of strictly commercial circles and people of large means the practice of depositing money with a banker is comparatively unknown. Small dealers, mechanics, and farmers, still adhere, in the main, to the old custom of hoarding, in feather-beds or underground, that has descended from the troublous days of the middle ages. That men should go from the extreme of unfounded distrust of stable and well-managed institutions into the incredible folly of pouring their money like water into the tills of a barefaced swindler, would seem to show that the springs of human action have not been raised very much; that a love of great gains, a desire to get more than our money's worth, a credulous faith in the performance of impossible promises are still deeply rooted, and need but the stimulus of some new and untried humbug to develop an amazing number of credulous fools.

LITERARY NOTICES.

Knight's American Mechanical Dictionary. A Description of Tools, Instruments, Machines, Processes, and Engineering; History of Inventions; General Technological Vocabulary; and Digest of Mechanical Appliances in Science and the Arts. By Edward H. Knight, Civil and Mechanical Engineer. 3 vols. Pp. 2831; 7395 cuts. New York: Hurd & Houghton. Price (cloth), $8 per vol.

This comprehensive and valuable work belongs in the rank of the cyclopædias, although its author has seen fit to choose for it the less ambitious title of a dictionary. It is qualified as mechanical, and answers to this description, but mechanics goes deep and sweeps wide in the field of Nature and art. Indeed, philosophers are split into factions over the question how far mechanics actually extends in the economy of the world, some maintaining that even cerebral action in processes of thought is resolvable into mechanical elements and conditions. But, without going so far as this, it is indisputable that mechanical changes are extensively and profoundly involved in the ongoings of the material universe. It is a vulgar notion that the term mechanics is restricted to cog-work and belting, wheels, levers, and pulleys, and a glance at Mr. Knight's voluminous exposition of the present state of knowledge on mechanical subjects will quickly dispel the narrow notions that may have hitherto prevailed regarding it. As stated in his prospectus, "the work deals with the *mechanical side* of every subject that can be known or mentioned, and, as almost everything in the universe has a *mechanical side*, the work becomes encyclopedical."

Mr. Knight seems to be a man cut out for such an enterprise. He began it twenty-five years ago, and as the volumes, in their vast and accurate detail, abundantly show, he must have had an enthusiasm for the work that kept him at it with untiring patience and perseverance; but as mere industry, although a prime factor in the result, must have been insufficient unless acting in the most favorable circumstances, he went to the headquarters of opportunity in this country, the Patent-Office at Washington. He was here "engaged in the editing the Patent-Office Report" and classifying patents; and subsequently editing the *Official Gazette* and systematizing for examination the twenty thousand applications for patents which are yearly presented at the office. Sitting at the very centre and focus of the mechanical thought of the country, he had both the stimulus and the facilities for carrying out his long-cherished purpose, and the "Dictionary" no doubt owes its exhaustive completeness to the free command of facilities afforded by his position.

We know of nothing that more impressively illustrates both the great advance of knowledge in this sphere of science and art, and the great activity with which it is at present cultivated in all civilized countries, than a critical glance at the pages of this elaborate work. And its statements are so presented as to bring out this view most impressively. Mr. Knight has introduced a subsidiary feature of "special indexes," which is not only very useful to those who consult his work, but shows in a striking way the extent to which inventive

construction has been carried in special lines of inquiry. For example, under the term "metre," we have a list of 218 instruments or machines for measurement, the description of each being found under its proper alphabetical heading. "These specific indexes afford the reader an excellent opportunity for investigating thoroughly all that pertains directly or indirectly to any special subject, by using the index under the title of that subject as a sort of head-centre, and following out its various branches through all their ramifications."

The work includes about 20,000 titles, and gives an exhaustive vocabulary of the technical terms that are employed in various trades and manufactures, and many of which are not to be found in the current large dictionaries. The work is, in fact, little less than a mechanical library, summarizing an endless multitude of books, and bringing up its accurate information to the present time. Of people who read and think at all, it is hard to think of any class that will not find it serviceable.

A Course of Elementary Practical Physiology. By M. Foster, M. D., F. R. S., Fellow of, and Prælector in, Physiology in Trinity College, Cambridge. Assisted by J. N. Langley, B. A., St. John's College, Cambridge. Macmillan & Co. Pp. 244. Price, $2.00.

As the sciences come to be more and more studied, directly and practically, there arises the necessity for books of special guidance in laboratory-work. In chemistry, treatises upon manipulation are as old as the science, and in recent years various works have been published, instructing the student in physical manipulations. The same necessity is now beginning to be felt in physiological study, and Prof. Foster's little hand-book now appears to supply this want for English-speaking students. The book has grown out of Dr. Foster's practice as a teacher. When in University College, London, he was in the habit of distributing among his students a syllabus to guide them in their work. This became extended, by the introduction of details, into a practical course, which is now published for general use wherever physiology is pursued, experimentally, or by the observation and verification of its facts.

Dr. Foster recognizes that the introduction of the microscope has given a direction to manipulative activity that is not altogether favorable to broad physiological study. The importance of histology is not questioned, but the tendency has been to pursue it separately, and to a certain extent to accept it as a substitute for physiological work on a large scale. Dr. Foster thinks that microscopical investigation can only be best pursued in combination with a full scheme of physiological work. He says: "Histological work, unless it be salted with the salt, either of physiological or of morphological ideas, is apt to degenerate into a learned trifling of the very worst description; and students are generally only too ready to spend far too much of their time in the fascinating drudgery of cutting sections and mounting stained specimens." And again: "The student who has mounted an exquisitely and beautifully stained section is only just so much the worse for his pains (as far as physiology is concerned) if he does not understand what the section means. Hence, when the features of some of the fundamental tissues and the general working of the more important mechanisms have been really learned, and the student has got, by doing things for himself, to know the value of a physiological experiment, and the pitfalls that are hidden under carmine and Canada balsam, he may be safely trusted to fill in the details of his study by means of reference to mounted specimens and to mere demonstrations, or even to descriptions of experiments."

Though the work is elementary, and is designed to be introductory to the author's "Hand-book for the Physiological Laboratory," it is, nevertheless, comprehensive, and covers the ground that should be passed over practically by every well-educated medical man. When our medical institutions provide better for this form of study, we can trust ourselves more safely in the hands of their graduates.

The Religion of Evolution. By M. J. Savage, Author of "Christianity the Science of Manhood." Boston: Lockwood, Brooks & Co. Pp. 253. Price, $1.50.

The multiplication of works on the religious bearings of Evolution, against it and

for it, attests the strong interest that is taken in this aspect of the doctrine, and, as interest is ever the first condition of active inquiry, this deep concern about the religious import of the theory is of great advantage, no matter what the basis may be. Probably nine-tenths of the opposition to the doctrine is theological in its inspiration and its form, there being no end to the books which have been issued during the last dozen years to prove that it is anti-religious and atheistic. But the discussion has already led to a reaction, or to a modification of extreme views; that is, it is admitted, even by those who rank themselves as opponents of the doctrine, that it is not *necessarily* either atheistic or irreligious. But these assaults upon Evolution have, moreover, called out defenses of it on the part of the religious, which have not only been useful in concentrating attention upon the subject, but have been very valuable in their liberalizing influence, and the light they have thrown upon the problem of religion itself.

To those who care for the religious aspects of the question, whether as involving the religious sentiments to which the doctrine is claimed to be favorable, or the influence it is exerting upon theological belief, the present work may be decisively commended. Its author is a liberal Unitarian clergyman, who took up the subject in a series of Sunday discourses, which were subsequently revised for publication in their present form. His treatment of the subject, which is entirely in its theological relations, is able and independent, and is presented in a clear, spirited, and eminently readable style. He aims to show that Evolution is not destructive of the religious sentiment; that it favors the most exalted conception of God; that it brings Nature into harmony with elevated religious feeling, and must be of great service to humanity in sweeping away many superstitions that have grown up in times of ignorance and become associated and deeply involved with religious emotions. Mr. Savage is at no pains to conceal the fact that he is not orthodox, and avails himself of many opportunities to hit his theological opponents, but he can hardly be expected to start new fashions in the pulpit, and the opportunity of position in the argument is too tempting to be resisted. There are numerous passages in this volume that we should be glad to quote, as where he treats of the practical character of the discussion, the immense influence on the thought of Christendom of the Mosaic cosmogony, and his chapter on the "Evolution of Conscience," but our space will not allow of quotations. We must refer the reader to the volume, which he will find fresh, piquant, and instructive.

Public Libraries in the United States of America: Their History, Condition, and Management. Special Report. Department of the Interior: Bureau of Education. Part I. Washington: Government Printing-Office. Pp. 1187.

This huge volume, which is the exponent of the public reading in this country, is an extensive cyclopædia on the subject of libraries. The statistics which have been published annually by the United States Commissioner of Education have been too limited to satisfy an inquisitive public, which wanted to know everything relating to books, from the arrangements necessary for organization to the best manner of preventing the volumes from being soiled.

This centennial offering will give much gratifying information to the true American, showing him that a great advancement has been made in the intellectual as well as in the material resources of the country. Thus, in 1776, there were twenty-nine public libraries in the colonies, containing 45,623 volumes. Now there are reported to be 3,682 libraries, numbering from 12,000,000 to 15,000,000 volumes, including pamphlets. Started in connection with the district-schools in New York and Massachusetts, free public libraries in some form have been established in the majority of the States of the Union; and it is believed that in no other country do so many libraries publish catalogues and reports.

The report is occupied with giving, first, the history of public libraries in the United States; second, their present condition and extent; third, a discussion of the various questions pertaining to library economy and management; fourth, extended statistical information of all classes of public libraries. Subjects comparatively new are introduced, such, for example, as the advisability of establishing professorships of books and

reading in connection with college libraries; or the beneficial results that would be produced by the employment of art-museums in free public libraries. The report has been well managed and is well arranged. The literature is especially good, as the greater part of the writing has been done by the various librarians throughout the country.

The Theory of Color in its Relation to Art and Art-Industry. By Dr. Wilhelm von Bezold, Professor of Physics at the Royal Polytechnic School of Munich, and Member of the Royal Bavarian Academy of Sciences. Translated from the German by S. R. Koehler, with an Introductory Sketch by Edward C. Pickering. Illustrated by Chromolithographic Plates and Woodcuts. Price, $5.

The advantages of this work over others of a similar nature are derived from the fact that recognition is made of the recent progress in physiological optics. In the first part of the volume the theory of color is placed upon its proper basis in relation to science, showing the aid which the latter gives in the perception of colors, their system, and the law of mixtures. One of the leading features claimed for the book is its purpose to serve as a guide to the pictorial and decorative artist, giving him hints in regard to the color of leaves, of the sky, and of water; the use of Claude glasses; the effectiveness of small differences; the laws regulating the combination of colors, etc.

While the signature of the author is a good recommendation for the book, the names of Prof. Pickering and Mr. Koehler will greatly assist in the extension of its influence.

Chemia Coartata; or, The Key to Modern Chemistry. By A. H. Kollmeyer, A. M., M. D., Professor of Materia Medica and Therapeutics at the University of Bishop's College; Professor of Materia Medica and Pharmacy at the Montreal College of Pharmacy; and Late Professor of Chemistry, etc. Philadelphia: Lindsay & Blakiston. Pp. 111. Price, $2.25.

The author has prepared this work "in the hope that it will prove useful to all who, from business occupation or from any other circumstance, may not have sufficient time at their disposal to consult the more voluminous works" which have been written. With the exception of brief introductory remarks to the different subjects, the book is composed of tables. The work is valuable merely from the convenience of referring to it, but could not be recommended to those who are beginning the study of chemistry, as there are many simpler and more comprehensive treatises on the subject.

Notes on Building Construction. Arranged to meet the Requirements of the Syllabus of the Science and Art Department of the Committee of Council on Education, South Kensington. Part II. Commencement of Second Stage or Advanced Course. London, Oxford, and Cambridge: Rivingtons.

This second part is in no respect inferior to the first, and the interesting manner in which difficult subjects are discussed tends to fulfill the prediction that the different parts, when united, would make up a "body of principles on the subject of great value to practical men." Some of the subjects which appeared in the first part are here treated more minutely, and others of a more involved nature are introduced. Among the latter are "Centres," "Stairs," "Riveting," "Fireproof-Floors," "Painting," "Paper-hanging," and "Glazing." A third part is to follow soon, completing the work.

Twenty-first Annual Report of the Board of Directors of the St. Louis Public Schools, for the Year ending August 1, 1875.

From this report it appears that the number of pupils in the day-schools during 1874–'75 was 35,941; in the evening-schools, 5,751—showing a large increase in the latter. Of the day-school teachers, the males form but ten per cent. No discrimination is made in the salaries in favor of male teachers, and a competent woman, in the position of "supervising principal" obtains a salary of $2,200 per annum. The salaries distributed in the year reported amounted to $531,850. All departments of the public-school system are said to be in the most flourishing condition. In connection with the schools there is a public library which gives gratifying results of its usefulness.

Prehistoric Remains at Cincinnati. By Robert Clarke.

This is valuable as a memorandum of the prehistoric remains found on the site of the city of Cincinnati, which have already been obliterated, or are fast becoming so, by the extension of the city. It shows careful research. The main object of the pamphlet, however, is the vindication of the claims to importance of the "Cincinnati tablet" (engravings of which are given) found in a mound on Fifth Street, in 1841, by Mr. E. Gest. One face is sculptured, in low-relief, with hieroglyphics, which, from their singular resemblance to Egyptian carvings, excited much attention. It was accepted as genuine for thirty years, when doubt was thrown upon it by several writers, and since then it has been by many considered as a fraud. Mr. Clarke now brings forward a mass of direct evidence to show its genuine character as a true relic of the mound-builders, which it would seem hard to contradict; and adds that many who for a time believed the tablet an imposture are now convinced of its genuineness. No explanation of its significance or use, however, is attempted, except incidentally. Archæologists will be glad to read this paper.

The Greenstones of New Hampshire, and their Organic Remains. By George W. Hawes.

This is reprinted with a colored plate from the *American Journal of Science and Arts*. The greenstones referred to cover the upper end of the Connecticut Valley, and belong to the Huronian age, but the author considers them to have been formed from fine sedimentary deposits accumulated in still waters; that the metamorphic action under which they were consolidated was quiet or gentle in degree, far different from that which in the adjoining regions formed mountain-masses of granite and gneiss, and hence that their special location, in connection with the nature of the sediments, has determined the characters of the greenstone series. In certain of these rocks silicated remains of rhizopods and foraminifers are found, and Mr. Hawes figures some as seen under the microscope, with their natural colors. The pamphlet is an instructive one to geologists and mineralogists.

Filth-Diseases and their Prevention. By John Simon, M. D., F. R. C. S., Chief Medical Officer of the Privy Council, and of the Local Government Board of Great Britain. Printed under the Direction of the State Board of Health of Massachusetts. Boston: James Campbell. Pp. 96. Price, $1.

This book is well recommended by the Board of Health of Massachusetts, as it believes that, "if the practical suggestions made in it were acted on by all citizens, hundreds of lives now annually doomed to destruction would be saved, and the health and comfort of the people greatly increased." The work was originally published in England as a preface to a volume of excellent reports made by Government inspectors. The author first traces the characteristic diseases due to filth, such as diarrhœa, typhoid fever, cholera, etc.; next, the various forms under which filth operates; and, finally, the means to be taken to do away with its effects. He also discusses at some length the different closet-systems.

Fifty Years of my Life. By George Thomas, Earl of Albemarle. New York: Holt & Co. Pp. 420. Price, $2.50.

The Earl of Albemarle was born in the last year of the last century, and his recollections cover much interesting historical ground. The position of his family brought him in contact with royalty from his early youth, and many illustrious persons, civil and military, figure in these pages. The narrative is written in a gossipy and contented manner, characteristic of a man who has lived a long and enjoyable life.

Seventh Annual Report of the State Board of Health of Massachusetts.

This report is the careful compilation of an able committee, and the popularity which it has obtained is justly deserved. The authors emphasize the fact that "it is expedient to keep practical questions of sanitary law and work constantly before the people;" and they have accordingly presented the matter very forcibly. Such subjects as "Rivers Pollution" and "The Disposal of Sewage" are treated in their relations to disease. Aside from its local worth, the report is valuable on account of the general principles discussed.

The Davenport (Iowa) Academy of Sciences has sent us its first volume of "Proceedings," forming a neatly-printed book of 285 pages and 36 plates. Besides the records of meetings, catalogues of cabinet, etc., a large number of papers are included, which, although local in their nature, are yet of much general interest. Davenport is so situated as to afford many advantages to the student of Nature. The underlying limestone abounds in fossils of the Hamilton and Upper Helderberg groups; the rivers and ponds produce a remarkably fine development of molluscan life; while the close proximity of the prairies to the wooded bottom-lands affords a rich field for the botanist and the entomologist. This region was once the residence of a prehistoric people, who have left many obscure traces behind them, furnishing an abundance of material for the archæologist to ponder over. Among the essays are several reports of explorations of mounds at Albany, Illinois, and in the vicinity of Davenport, by Dr. R. J. Farquharson, and other archæological papers by C. Lindley, A. S. Tiffany, and J. D. Putnam; geological papers by W. H. Pratt; botanical matter by Dr. C. C. Parry, J. G. Haupt, and J. J. Nagel; lists of insects of Iowa and Utah, by J. D. Putnam; and studies upon land and fresh-water shells, by W. H. Pratt. This first volume is very creditable to the young Academy, and it is to be hoped a second similar publication may soon follow. We observe, by the-way, that it is published "for the Academy by the Women's Centennial Association," and suggest that this would be an excellent way for our many societies of zealous women to spend their money in other cities than Davenport.

An Elementary Hand-book of Theoretical Mechanics, with One Hundred and Forty-five Diagrams. Pp. 146. Price 75 cents.—An Elementary Hand-book of Applied Mechanics, with Eighty-eight Diagrams. By William Rossiter, F. R. A. S., F. C. S., F. R. G. S. New York: Putnams.

These two volumes form a mean between the commonly-received elementary treatises on the subject and the more advanced works. While they are simple enough for easy comprehension, they contain many of the data necessary for an advanced student.

Henry Holt & Co. are just putting to press, in hope of having it ready by the end of the year, a "Classical Literature" by C. A. White, whose "Mythology" has been received with much favor. The book will contain biographical and critical notices of the leading writers in Sanskrit, Greek, and Latin, with specimens of their works, and some account of the relations of the languages.

PUBLICATIONS RECEIVED.

The Germ-Theory of Disease. By J. Maclagan, M. D. Pp. 266. London: Macmillan.

The Functions of the Brain. By D. Ferrier, M. D. Pp. 338. New York: Putnams. Price, $3.50.

The Carlyle Anthology. Selected by E. Barrett. Pp. 396. New York: Holt & Co. Price, $2.

David and Anna Matson. By Abigail Scott Duniway. Pp. 194. With Illustrations. New York: S. R. Wells & Co. Price, $2.

Octavius B. Frothingham and the New Faith. By E. C. Stedman. Pp. 50. New York: Putnams. Price, 75 cents.

An Alphabet in Finance. By Graham McAdam. Pp. 230. Same publishers. Price, $1.25.

Modern Physical Fatalism. By T. R. Birks. Pp. 311. London: Macmillan. Price, $2.25.

Geographical Surveys west of the One Hundredth Meridian (Wheeler). III. Pp. 681. With Plates. Washington: Government Printing-Office.

Chemistry Theoretical and Practical. Parts X. to XIV. Philadelphia: Lippincott & Co. Price, 50 cents each.

Proceedings of the Poughkeepsie Society of Natural Sciences. Vol. I., Part I., Pp. 150.

Prometheus. Weekly Magazine. Vol. I., No. 1. Pp. 28. New York: Charles P. Somerby. Price, $3 per year.

Proceedings of the American Chemical Society. Vol. I., No. 1. Pp. 80. New York: Trow & Co., printers.

Valedictory Address at the Indianapolis College of Medicine. By E. D. Foree, M. D. Pp. 19. Indianapolis: *Journal* print.

Report of the New York Meteorological Observatory. By D. Draper. Pp. 48. New York: *Evening Post* print.

Report of the Commissioner of Agriculture. Pp. 19. Washington: Government Printing-Office.

Field and Forest. Monthly. Vol. II., No. 5. Pp. 8. With Plate. Washington: The Columbia Press.

Mayer's Ontogeny and Phylogeny of Insects. *Also*, A Century's Progress in American Zoölogy. By A. S. Packard, Jr. Pp. 4 and 8.

Immediate Preparation and Early Resumption. By R. T. Paine, Jr. Pp. 31. Boston: A. Williams & Co.

A System of Marine Signals. By S. P. Griffin. Pp. 13. New York: Van Nostrand.

Appalachia. Organ of the Appalachian Mountain Club. Pp. 62. With Maps. Boston: A. Williams & Co.

Education and Progress: an Address by General T. M. Logan, of Virginia. Pp. 16.

Relations of Physical Health to Morality and Religion. By Rev. G. W. Cooke. From the *Herald of Health*. Pp. 8.

Death-Rate of each Sex in Michigan. By H. B. Baker, M. D. Pp. 16. Cambridge, Mass.: Riverside Press.

POPULAR MISCELLANY.

Deep-Sea Bottom Deposits.—The deep-sea bottom deposits found by the Challenger expedition are classified as follows by Mr. Murray, naturalist on the scientific staff:

1. Shore-deposits, and these are mud of a variety of colors, as blue, gray, green, red, also coral-mud and sands; 2. Globigerina ooze; 3. Radiolarian ooze; 4. Diatomaceous ooze; 5. Red and gray clays. To these may be added peroxide of manganese in nodules and grains widely diffused.

The character of the sea-bottom contiguous to the shores is determined largely by that of the adjacent lands. Thus coral-mud occurs in the vicinity of coral-islands, and volcanic products near volcanic districts.

This general feature of the coast extends in some cases 150 miles seaward; an exception was found, however, among the coral-islands of the Pacific, where the coral-mud occurs as a narrow band around the islands.

Globigerina ooze is the most abundant deep-sea deposit next to the clays. It does not occur in the inclosed seas in the Pacific north of latitude 10° north, nor south of latitude 50° south.

Radiolarians occur in most seas, but only in limited areas are they sufficiently abundant to give a distinctive character to the ooze. In the Antarctic Ocean a diatom ooze is found, and radiolarian ooze was brought up from the great depth of 4,475 fathoms—nearly four and three-quarter miles. The skeletons of these minute organisms are siliceous.

The red clay is the most abundant deposit, and below depths of 2,000 fathoms is very widely diffused. The skeletons of siliceous organisms are abundant in it, but calcareous shells are few, and in some specimens wholly wanting. The author seems to refer the origin of the red and gray clays to lavas, scoriæ, pumice, volcanic ashes, and possibly meteoric or cosmic dust; and adds, "If there be an ash after the carbonate of lime is removed by acid or other agent, this will be another source." But Prof. Wyville Thomson distinctly states that the red clay is essentially the insoluble ash or residue of calcareous organisms which form the globigerina ooze, after the calcareous matter has been removed; and this conclusion is confirmed by the very careful experiments made by Mr. Buchanan, who treated the ooze with dilute acids.

The author states that efforts to detect free protoplasm in the dredgings was attended by no definite result. Some specimens, however, assumed a jelly-like aspect, with flocculent matter when in spirits. This flocculent matter was found by Mr. Buchanan to be "sulphate of lime precipitated from sea-water, and the author infers that the so-called 'Bathybius' and the amorphous sulphate of lime are identical." In this connection he quotes a report on the subject by Mr. Buchanan which states

that "the substance when analyzed consisted of sulphuric acid and lime, and, when dissolved in water and the solution allowed to evaporate, it crystallized in the well-known form of gypsum; the crystals being all alike, there being no amorphous matter among them." Mr. Murray's conclusion is that in "placing Bathybius among living things the describers of it committed an error."

Eccentricity in Wood-Growth.—Mr. T. S. Gold writes as follows, in the *Gardener's Monthly*, concerning the unequal deposition of wood in growing trees but partially exposed to the action of the wind: "A choke-cherry sprang from seed in front of my piazza, close to it, and could only be moved by the winds laterally. The section of the trunk was elliptical, the longer diameter being nearly double the shorter. Since the tree has grown above the roof of the piazza the trunk is becoming less elliptical. A young plum-tree standing close by the side of an out-building was killed by mice, and the sprouts were allowed to grow. These were all elliptical like the cherry, and made most wood on the two sides. It appeared to me that the trees made wood where it was most needed, on the sides where the strain of the wind came. Sometimes the eccentricity is produced by large branches or large roots on one side of the stem, and in other cases these seem to have little influence." This accords with the view of Mr. Herbert Spencer, who, in the appendix to his second volume of "Biology," gives the history of an interesting course of experiments "On Circulation and the Formation of Wood in Plants."

Notes on the British Arctic Expedition.—Of the two ships constituting the British Polar Expedition, the Discovery, Captain Stephenson, wintered at Cape Baird, latitude 81° 40′; and the Alert, Captain Nares, at Cape Union, latitude 82° 30′. The site of the supposed "Open Polar Sea" was found to be occupied by a rigid sea of ice, called the Paleocrystic Sea, or Sea of Ancient Ice. The thickness of this ice is enormous, varying from 80 to 120 feet. This Paleocrystic Sea is no doubt the accumulation of many years, or even of centuries. The lowest temperature experienced by the expedition was 104° Fahr. below freezing, which is 20° below the minimum observed by the Polaris Expedition. The sun was absent 142 days. A sled-party from the Alert planted the British flag in latitude 83° 20′ 26″; but, as they had to hew a track through the exceedingly rough surface of this frozen sea, seventy-two days were spent in accomplishing the journey. Another party explored the coast-line westward for a distance of 220 miles. The most northerly point of the coast of Grant Land was found by this party to be Cape Columbia—latitude 83° 7′, west longitude 70° 30′. The Greenland coast was explored by a party from the Discovery, and its most northerly point found to be in latitude 82° 50′, west longitude 43° 30′; thence the coast trends in a southeastern direction. A good seam of coal was discovered near the winter-quarters of the Discovery. A brass tablet with the following appropriate inscription was fixed on the grave of the gallant American explorer, Captain Charles Francis Hall: "Sacred to the memory of Captain C. F. Hall, of the U. S. ship Polaris, who sacrificed his life in the advancement of science on November 8, 1871. This tablet has been erected by the British Polar Expedition of 1875, who, following in his footsteps, have profited by his experience."

Sexual Selection among the Monkeys.—Mr. Darwin, in his "Descent of Man," holds that the brilliant coloring of the face in the male mandrill, and of the posterior callosities in that and sundry other species of monkeys, is the result of sexual selection. He now, in a communication to *Nature*, brings forward some new observations on this subject made by Joh. von Fischer, of Gotha. Von Fischer finds that not only the mandrill, but the drill and three other kinds of baboons, which he names, also *Cynopithecus niger*, *Macacus rhesus*, and *M. nemestrinus* turn the hind-parts of their bodies, which in all these species is more or less highly colored, toward him when they are pleased, and toward other persons as a kind of greeting. Many other facts of a like nature are mentioned by Mr. Darwin, and then he expresses the opinion that "the bright colors, whether on the face or hinder end, or, as in the mandrill, on both, serve as a sexual ornament and attraction. Any-

how," he continues, "as we now know that monkeys have the habit of turning their hinder ends toward other monkeys, it ceases to be at all surprising that it should have been this part of their bodies that has been more or less decorated. The fact that it is only the monkeys thus characterized which, as far as at present known, act in this manner as a greeting toward other monkeys, renders it doubtful whether the habit was first acquired from some independent cause, and that afterward the parts in question were colored as a sexual ornament; or whether the coloring and habit of turning round were first acquired through variation and sexual selection, and that afterward the habit was retained as a sign of pleasure or as a greeting, through the principle of inherited association."

The Transmission of Habit.—A correspondent of *Nature*, resident in New Zealand, communicates to that journal several instances of the transmission of habits to offspring in animals. One instance is that of a mare which would wander away from the "mob" of horses to which she belonged—always seeking one particular creek. When released from work she would make off to her favorite feeding-ground by herself. One of her progeny some years after showed a similar liking for solitude. Again, a valuable mare was an incorrigible kicker; she transmitted her special vice to her offspring. Peculiarity in the form of the hoof has been transmitted to generation after generation. The same writer states that a particular strain of Dorking fowls which he has had in his possession for thirty years always show a restless desire for rambling, and this, too, under the difficulty of meeting with much persecution when straying beyond their range.

Efforts to stop the Locust-Plague.—In October a convention of the Governors of several Western States and Territories was held at Omaha, to devise means of withstanding the plague of locusts. Besides the Governors, there were present at the meeting a number of prominent farmers and scientific men. A memorial to Congress was adopted, setting forth the serious injury done to agriculture by the locust, and asking for the appointment of a commission to investigate the "history and haunts of this insect; also all possible means of its extermination, and remedial agencies which may be used against it." Prof. Riley, of St. Louis, delivered an address, in which he briefly narrated the habits and history of the Rocky Mountain locust. He considered that there were two main questions before the conference: 1. How best to deal with the young insects that threaten to hatch out over a vast extent of the country next spring; and, 2. The investigation of the insect in its native home, with a view of preventing its migrations into the country to the south-east. Prof. C. D. Wilber, of Nebraska, gave an account of the various means adopted in different parts of the West to counteract this plague. Governor Pillsbury, of Minnesota, gave a history of locust-ravages in various countries. Governor Pennington, of Dakota, offered a series of resolutions "respectfully but earnestly urging that all our people in the States and Territories afflicted by the locust-plague, of all denominations and sects, offer up special prayers in their respective churches for deliverance from this great enemy."

Insect Fertilization of Plants.—For a year Mr. Thomas Meehan has been making observations and experiments to determine whether insects are of material aid to plants in fertilization. His results, which are published in the *Penn Monthly*, appear to favor a decision of the question in the negative. That insects sometimes fertilize and cross-fertilize flowers, he admits, but he holds that these cases are less frequent than they are supposed to be, and that, when they do occur, they have no bearing on the general welfare of the race. The chief arguments for the necessity of insect fertilization, says Mr. Meehan, are drawn from structure and not from facts of observation. Thus it is stated that *Iris*, *Campanula*, dandelion, ox-eye daisy, garden pea, *Lobelia*, clover, and many other plants, are so arranged that they cannot fertilize themselves without insect aid. But the author has inclosed flowers of all of these in fine gauze bags, and found that they produced seeds as well as other flowers that were exposed. And yet *Iris Virginica* and *Campanula* are common

illustrations of the supposed necessity of insect fertilization. In one plant experimented with in this way (*Baptisia*), seeds were not formed. This plant, in the author's opinion, may possibly require insect agency for its fertilization. He does not deny that flowers are *sometimes* fertilized by the aid of insects; but he does not admit that this mode of fertilization is very common. His conclusions may be stated as follows: 1. That cross-fertilization by insect agency does not exist nearly to the extent claimed for it; 2. That, where it does exist, there is no evidence that it is of any material benefit to the race, but contrariwise; 3. That difficulties in self-fertilization result from physiological disturbances that have no relation to the general welfare of plants as species.

Proposed International Geological Congress.—A committee appointed by the American Association has issued a circular addressed to geologists, announcing the proposed convocation of an International Geological Congress, to be held at Paris some time during the Exposition of 1878. It is proposed to make the Congress an occasion for considering many disputed points in geology, and to this end it is desirable that the Geological Department of the Exhibition should embrace—1. Collections of crystalline rocks, both crystalline schists and massive or eruptive rocks, including the so-called contact-formations and the results of the local alteration of uncrystalline sediments by eruptive masses. In this connection are to be desired all examples of organic remains found in crystalline rocks, including Eozoon and related forms. These collections should, moreover, comprehend all rare and unusual rocks of special lithological, mineralogical, and chemical interest, examples of ore-deposits and of vein-stones of all kinds, with their incasing rocks. As far as possible these collections should be limited to specimens of a size convenient for examination, and be accompanied with sections prepared for microscopic study.

2. Collections illustrating the fauna and the flora of the Palæozoic and more recent periods, particularly of such horizons as present a more critical interest to paleontologists from the first appearance or the disappearance of important groups of organic forms. It has appeared to the committee that the organic remains of the Cambrian, Taconic, or so-called Primordial strata merit especial attention in this connection.

These various collections should be explained as fully as possible by labels, catalogues, monographs, and maps.

3. Collections of geological maps, and also of sections and models, especially such as serve to illustrate the laws of mountain-structure. In the geological maps, regard should be had to various questions which deserve the special consideration of the Congress, such as the scales best adapted for different purposes, the colors and symbols to be used, and the proper mode of representing superficial deposits conjointly with the underlying formations. The secretary of the committee is Dr. T. Sterry Hunt, of Boston.

Comparative Dietetic Value of Meat and Eggs.—A writer in the *Scientific Farmer* estimates the food-value of one pound of eggs as a producer of force, i. e., the amount of work the pound oxidized in the body is theoretically capable of producing, at 1,584 foot-tons, and the value of one pound of lean beef, from the same point of view, at 990 foot-tons. As a flesh-producer, one pound of eggs is about equal to one pound of beef, as is shown by the following analysis quoted by the author:

ONE POUND OF EGGS.

Water	12 oz., 36 grs.
Albumen	2 oz.
Extractive	130 grs.
Oil or fat	1 oz., 214 grs.
Ash	28 grs.

Will produce at the maximum 2 oz. of dry muscle or flesh.

ONE POUND OF BEEF.

Water	8 oz.
Fibrine and albumen	1 oz., 122 grs.
Gelatine	1 oz., 62 grs.
Fat	4 oz., 340 grs.
Mineral	350 grs.

The author hereupon remarks as follows:

"A hen may be calculated to consume 1 bushel of corn yearly, and to lay 12 dozen or 18 pounds of eggs. This is equivalent to saying that 3.1 pounds of corn will produce, when fed to this hen, 1 pound of eggs. A

pound of pork, on the contrary, requires about 5½ pounds of corn for its production. When eggs are 24 cents a dozen, and pork is 10 cents a pound, we have the bushel of corn fed producing $2.88 worth of eggs, and but $1.05 worth of pork.

"Judging from these facts, eggs must be economical in their production and in their eating, and especially fitted for the laboring-man in replacing meat."

Qualifications of Medical Students.—At the opening of the medical session of Glasgow University, last week, Prof. McCall Anderson said few could doubt that a preliminary examination of candidates for admission to the classes was called for, but if proof were required it might be found in the answers given to the following questions submitted to candidates by one of the examining boards: "What is meant by the antiquity of man?" Answer: "The wickedness of man." "The Letters of Junius?" "Letters written in the month of June." "The Crusades?" "A war against the Roman Catholics during the last century." "The first meridian?" "The first hour of the day." "To speak ironically?" "To speak about iron." "A Gordian knot?" "The arms of the Gordon family." "The Star-chamber?" "Place for viewing the stars." "To sit on the woolsack?" "To be seated on a sack of wool." "A solecism?" "A book on the sun." "The year of jubilee?" "Leap-year." They could, the professor added, have appreciated this last answer all the more heartily had it emanated from one of the female medical students. It is, however, only just on women to admit that they are, as a rule, serious in their studies, and are not in the habit of joking examiners. There is, indeed, an earnestness of purpose in their efforts to compete with man which entitles them to respect, and even imitation.—*Pall Mall Gazette.*

The Struggle for Existence.—Prof. Alfred Newton, in his address to the Biological Section of the British Association, described as follows the effects consequent upon the introduction by man of foreign species of animals into newly-discovered regions: "Set face to face with unlooked-for invaders, and forced into a contest with them from which there is no retreat, it is not in the least surprising that the natives should succumb. They have hitherto only had to struggle for existence with creatures of a like organization; and the issue of the conflict which has been going on for ages is that, adapted to the conditions under which they find themselves, they maintain their footing on grounds of equality among one another, and so for centuries they may have 'kept the noiseless tenor of their way.' Suddenly man interferes, and lets loose upon them an entirely new race of animals, which act and react in a thousand different fashions on their circumstances. It is not necessary that the new-comers should be predacious; they may be so far void of offense as to abstain from assaulting the aboriginal population; but they occupy the same haunts and consume the same food. The fruits, the herbage, and the other supplies that sufficed to support the ancient fauna, now have to furnish forage for the invaders as well. The new-comers are creatures whose organization has been prepared by and for combat throughout generations innumerable. Their ancestors have been elevated in the scale of being by the discipline of strife. Their descendants inherit the developed qualities that enabled those ancestors to win a hard-fought existence when the animals around them were no higher in grade than those among which the descendants are now thrown. The struggle is like one between an army of veterans and a population unused to warfare."

Economy in the Use of Steam.—A series of experiments has been made, as we learn from *Iron*, upon the 80-horse-power engine at Portsmouth dock-yard, for the purpose of testing the value of a process, the invention of Mr. Marchant, of London, whereby steam, after having done its work in the cylinder, is pumped back into the boiler, to be re-utilized for steam-power. The advantage which the inventor claims for his invention is a considerable saving of fuel, because, inasmuch as it is economical to keep the boilers supplied with hot water from the condensers instead of cold water, it follows that to keep them supplied with steam direct from the cylinders must prove still

more economical of fuel. The experiments appear to have been successful. The engine one day was worked as an ordinary condensing engine, when it was found that the consumption was 1,176 pounds of coal in six hours, producing an indicated horse-power of 84.747. The next day the engine was driven with Marchant's steam-pumps connected with the low-pressure cylinder; the consumption of coal was now 1,158 pounds, while the indicated horse-power was 104.123. The ascertained work on the steam-pumps was six indicated horse-power.

Gathering Rock-Crystals.—Searching for rock-crystals is one of the recognized industries of the Swiss Alps, and the men who follow this vocation are known as *Strahlers*. The following notes upon the search for these crystals we take from the *Moniteur Industriel Belge:* The outfit of a *Strahler* consists of a bar of iron four feet long and bent at one end, a shovel, a pick-axe, a hammer, a stout cord, and a leathern sack. Thus equipped, he goes out to his work in the morning. He nearly always goes alone, so as to have all he may find for himself. For hours and hours he creeps along the sides of the rock, on projections of a few inches, over yawning chasms. When he descries a vein of quartz, he strives to reach it, but oftentimes this is a matter of extreme peril, and involving much labor; he must be very careful where he steps, and not seldom he must hew out a resting-place for his foot in the rock. Having reached the vein, he follows it and strikes it with his hammer. His practised ear tells him whether he has to deal with a "cavern," a "druse," a "pocket," or a "kiln," as the various kinds of cavities are called in which are found the crystals—whether attached to the walls or loose and mixed with sand. The most famous discovery ever made of monster crystals is of very recent date. Some hundred feet above the snow-line an apothecary of Bern saw a vein of quartz 60 feet long and from 4 to 12 feet wide. On working the vein, four hundred-weight of crystals were taken out; the larger masses were purchased for museums, while the smaller pieces were sold to opticians.

NOTES.

The chemical laboratory for female students, in the new building adjoining the Massachusetts Technological Institute, has been thoroughly fitted up, and was occupied for the first time early in November.

Five specimens of ground coffee, chemically examined by C. H. Eddy, of Michigan University, were found to be adulterated to the extent of from 22 to 39 per cent. with chiccory. One package, labeled "Pure Mocha and Java," contained 23 per cent.; "Pure Rio," 25 per cent.; "Pure Java," 22 per cent.; "Royal Java," 31 per cent.; "Warranted pure government Java," 39 per cent. Besides chiccory, these prepared coffees consisted chiefly of peas, oats, starch, carrots, etc. In three of the five specimens no caffeine could be discovered.

White-lead, as a pigment, is chiefly valued for its "body," and for the ease with which it is laid on; but it produces lead-poisoning, and also tends to lose its whiteness. Zinc-white is not open to these objections. Properly prepared, it has as good covering properties as white-lead, and the addition of magnesia in the manufacture makes it as easy to work; besides, it has no injurious effects on the health of those who manufacture or use it.

An extensive deposit of plumbago has been discovered in Longswamp Township, Berks County, Pennsylvania. "The deposit," says the *American Manufacturer*, "is between seven and eight feet in depth, and the mineral is of the best quality. Similar deposits are supposed to exist elsewhere in the same region, and persons are now engaged in prospecting, but as yet no new discoveries have been made."

The *Library Table* for November contains a good sketch of the life and works of Mr. Darwin, with portrait. A valuable feature of this periodical is its classified index to current periodical literature.

The death is announced of the eminent French geologist, Charles Sainte-Claire Deville, at the age of sixty-two years. He was a native of the island of St. Thomas, graduated from the Paris School of Mines, studied the geology of the Antilles, and published the results of his investigations in 1856. Later he was Professor of Geology in the Collége de France. For many years he devoted himself to the study of meteorology, and to him in great measure is due the foundation of the Montsouris Meteorological Observatory.

No publications by professors or other *attachés* (*quære:* officers, students, resident

graduates?) of the Johns Hopkins University are permitted to be issued in the name of, or dated from, the university, without the consent of the professor to whose department the subject-matter belongs, or, in defect of such professor, of the head of the university.

The *Engineering and Mining Journal* proposes to its readers the following problem in proportion: If the German Continental Gas-Light Company is able to declare 13 per cent. dividends on its capital of nearly $3,000,000, when paying $5.75 per ton for its coal, and charging $1.01 and $1.35 per thousand feet for its 15.9 candle-gas, what are the profits of the New York gas companies, which pay $6 per ton for their coal, and charge $2.50 per thousand feet for a poorer gas?

In the School of Anthropology lately opened under the auspices of the Paris Faculty of Medicine, Prof. Paul Broca lectures on anatomical anthropology, M. F. Topinard on biological anthropology, M. Dally on ethnology, M. de Mortillet on prehistoric anthropology, and M. Hovelacque on linguistic anthropology. The course is open to the public.

Several members of the Paris Anthropological Society have promised each to write a will directing that his brain be sent to the society, for inspection and dissection. It is thought that, by procuring the thinking organ of persons whose habits and works are perfectly known, some light might be thrown on the laws of physico-mental organization. The scheme is anathematized by the leading religious newspaper of France, the *Univers*.

On and about pistons and journals which have been lubricated with animal and vegetable oils, lumps of dirty matter are found, consisting of iron oxide and fatty acids. Dr. Schöndorff has found that the oil is decomposed by steam into glycerine and fatty acid, and that the latter attacks the iron, causing enlargement of the cylinder. He therefore recommends the use of heavy mineral oils as lubricators.

An association has been formed and an estate purchased on the Sussex (England) coast, for building houses of a superior character, and on the most approved principles, so as to secure all the advantages depicted by Dr. Richardson as belonging to his "Hygeia," or City of Health.

The great maritime canal connecting Amsterdam with the German Ocean was opened November 1st, with imposing ceremony. The canal is sixteen miles in length, and has at the sea-end a harbor covering 250 acres, which, however, is not quite completed.

It is stated in *Land and Water*, as a fact beyond contradiction, that the choice English breeds of cattle have for some years not only tended to diminish in size, but also in robustness of constitution. The milk-yielding qualities of English cattle, too, are declining, so that the importation of cheese and butter is increasing enormously. This is strikingly the case with the Durhams, in which everything is sacrificed to form. In the finest strains of Durham cattle fecundity has been seriously affected, and the milk-secretion has become next to nothing.

The loss, in 1875, to Russia, from the ravages of wolves, amounted to about 15,000,000 rubles. The number of cattle killed was 179,000; of sheep, etc., 562,900. In the government of Kalouga alone the wolves killed 8,200 geese and 2,000 dogs. The human lives destroyed by the wolves are estimated at 200 per year.

At the fifth meeting of Russian naturalists, held at Warsaw, September 12th, proposals were favorably received to establish a zoölogical station on the Solovetzky Islands, and to request the aid of the Naval Department for dredgings in the Black Sea. Messrs. Grimm and Bogdanoff informed the meeting that they had undertaken two publications, a popular periodical, *Herald of Natural Science*, and a periodical in French or German, which would give to foreign readers brief notices of scientific work in Russia.

A miner at Nitshill, in Scotland, lately committed suicide by blowing himself up with dynamite. He procured a parcel of the explosive, went into the middle of the street, lighted the fuse, and leaned over the dynamite. The man was blown to atoms, and, on the spot where the dynamite had been laid, a hole was made about three feet deep by two and a half wide.

A commission appointed by the Government of Prussia to ascertain sundry anthropological data, has reported that of 4,127,776 pupils in schools, 42.97 per cent. had blue eyes, and 24.31 per cent. brown; 72 per cent. had blond hair, 26 per cent. brown, and 1.21 per cent. black. With regard to the color of the skin, only 6.53 had brunette complexion.

In a letter addressed to M. Dumas, of the Paris Academy of Sciences, M. Gachez asserts that vines may be protected from the ravages of the *Phylloxera* by planting "red maize" between the rows. The insect quits the vine and attacks the roots of the maize.

In 1849, out of every sixteen men, women, and children, in England and Wales, one was a pauper maintained by the charity of the remaining fifteen. In 1852 one in twenty was a pauper, and in 1875 only one in thirty.

JOSIAH PARSONS COOKE, Jr.

THE

POPULAR SCIENCE MONTHLY.

FEBRUARY, 1877.

THE TRIAL OF GALILEO.[1]

By A. MÉZIÈRES,

OF THE FRENCH ACADEMY.

MANY points have been left obscure in the history of the double trial of Galileo, the details of which till lately were but imperfectly known. The important work published by Domenico Berti[2] fills up some of these gaps, by placing before our eyes a collection of authentic documents taken from the secret archives of the Vatican. We have here no work of partisanship, undertaken in the interest of religious controversy, but an historical work executed with all the scrupulous care that is nowadays exacted in all historical researches. In France the question had already been handled by Libri, Biot, Joseph Bertrand, Trouessart, and Th. Henri Martin, the first two approaching it with preconceived opinions that aided but little in the discovery of the truth, while the others brought to the discussion a remarkable spirit of impartiality. But all of these writers lacked the indispensable elements of information which now, thanks to the labors of Domenico Berti, are at the disposal of the future biographers of Galileo. If we have suffered ourselves to be anticipated by an Italian in the publication of the documents relating to this famous case, we must attribute the fact either to the negligence or to the prudence of the French Government, for we were in possession, for nearly half a century, of the valuable manuscript the full text of which is now published by Berti. Having been taken out of the Vatican archives during the first empire and carried to Paris, this original collection was there seen by the historian Denina, but he thought it to be of no importance. Nevertheless Napoleon I. ordered it to be published, with a translation facing the text; but the publication, though begun,

[1] Translated from the *Revue des Deux Mondes* by J. Fitzgerald, A. M.

[2] "Il Processo Originale di Galileo Galilei, pubblicato per la prima volta," Roma, 1876.

was not continued: only the beginning of the work was then known, and of this Delambre, the astronomer, gave an account to the Italian Venturi.

In December, 1814, according to the Duke de Blacas, the private library of Louis XVIII. received the entire MS. in the same condition in which it had been found by the imperial government in Italy, and thence carried to France. During the early years of the Restoration, active negotiations were carried on by the court of Rome with the French Government, to secure the return of these important documents. The Government, though it did not positively refuse to comply, nevertheless delayed and procrastinated. It was not until 1846, after thirty-two years of negotiation, that the MS. was sent back to Rome, at the instance, no doubt, of Rossi, who himself presented it to Pius IX., in behalf of Louis Philippe. By the pope it was restored in December, 1848, to the secret archives of the Vatican, and there it still remains.

All that was known of this MS. before the publication of Berti's work rested upon a selection of documents published at Rome in 1850, with many precautions, by Monsignore Marino Marini, sometime Prefect of the Secret Archives of the Holy See, and upon a larger work, in some respects inexact, and in others imperfect, published in Paris in 1867, by Henri de l'Épinois. Both of these writers take special points of view: they appear to be more intent upon justifying the judges that condemned Galileo than upon laying bare the whole truth with the boldness and freedom of an historian. Hence we can appreciate the motives which led them to publish only a portion of the MS. though the whole of it was in their hands. Did the court of Rome really suppose that these two publications contained all the documents pertaining to the double trial of Galileo, or did it think that the time had come for no longer hiding anything from the public? However that may be, at all events Domenico Berti, in February, 1870, was permitted to examine the MS., and even to copy it at his leisure in the room of Father Theiner, who had been officially authorized to intrust it to him. The present publication, therefore, was not procured by fraud, and, if the Holy See should have any occasion to regret it, at least it could neither dispute its authenticity, nor complain that the work was done without its consent.

I.

The interesting history of the travels and of the final destiny of the Vatican MS. is merely the preface of a far more important history, whose events we will endeavor to record impartially, with the sole purpose of unveiling and bringing to light the truth. Galileo, celebrated from his early years for the value of his discoveries and the brilliancy of his lectures at the University of Padua, loaded with honors at Venice and at Florence, and admired throughout all Italy,

was pursuing the course of his great researches with the boldness of a man confident of his strength and of his fame, when certain slight indications no doubt warned him that it would not be disadvantageous, if he would carry on his researches in safety, to win the favor of the Sacred College. Accordingly he set out in 1611 for the Eternal City, without confessed misgiving, but with the ambition and expectation of interesting the most influential personages of the Roman court in his discoveries. He was nearing the decisive moment of his career. He had not as yet been disquieted by the objections of the theologians, though in prosecuting his studies of the constitution of the universe he was touching upon delicate questions which he could not expect to be permitted to discuss freely, without having first gained the sympathy, or at least the neutrality, of the Church. The court of Rome at that time exercised such moral authority in Italy, and especially at Florence, where Galileo resided, that people in some sense waited for her decision before they would accept the best-established conclusions in astronomy. The Grand-duke of Tuscany could not but be pleased at the discovery of Jupiter's satellites, announced in the "Sidereus Nuncius;" and he was all the more ready to believe, because these new heavenly bodies had received his family name: yet his own secretary had to admit that the discovery would never receive the unanimous assent of the learned world until it was approved and verified at Rome. There sat the Roman College, a regular tribunal, scientific as well as theological, whose decrees were law in Catholic countries.

Galileo, who was a man of rare good sense, and perfectly conversant with the ways of the world, had in advance formed at Rome the best and the most powerful of relations. Besides, he came there in a sort of official capacity, at the grand-duke's charges, and he was entertained there by the Tuscan embassador. Prelates, cardinals, princes, vied with one another for the honor of offering *fêtes* and banquets to the most illustrious representative of Italian science. At the palace of Cardinal Bandini, in the beautiful gardens of the Quirinal, in the villa of the Marquis Cesi on the summit of the Janiculan, Galileo delighted a society of *élite* by having them contemplate, during the serene nights of April, the vault of heaven through the telescope which he had recently invented, and which bears his name. He awakened a genuine enthusiasm one day when, after dinner, he pointed his telescope toward St. John of Lateran, three miles distant, and enabled the guests to read the inscription upon the façade of that basilica.

His arguments did not equally convince all of those who were present at his astronomical observations, and who listened to the explanation he gave of the movement of Jupiter's four satellites, the inequalities of the moon's surface, and the phases of Venus and Saturn, and to the discussions he carried on with those who opposed his views. His

doctrine implied the confirmation of the system of Copernicus and the demonstration of the earth's motion, which were no longer reserved for mathematicians only, but made intelligible to all by a series of experiments. Here was an innovation calculated to alarm the theologians. A system that might be regarded as inoffensive so long as it was only a mathematical hypothesis, useful to men of science in their researches, became a very different thing on being transformed into a physical truth accessible to the senses and pregnant with consequences touching the plurality of worlds and the aim of creation. Hence the apparent triumph of Galileo hid from view perils the magnitude of which at first eluded his penetrating mind. While he was giving himself up, with perhaps over-much confidence, to the pleasure of success, and was yielding too easily to his habitual temptation to answer objections with sarcasm, the ecclesiastical authority quietly set on foot an inquiry into the orthodoxy of his opinions. Cardinal Bellarmin, probably in the name of his colleagues of the Inquisition, asked of the members of the Roman College (without mentioning Galileo's name) what was to be thought of the astronomical observations that had recently been promulgated by a distinguished mathematician.

This is the first symptom that we have been able to discover of the intervention of theology in the examination of Galileo's scientific opinions. The response of the Roman College was favorable to him; but, from that moment forward, the alarm was sounded, and the Inquisition never lost sight of him. Though the sovereign pontiff, to whom he was presented by the Tuscan embassador, received him with great courtesy, not allowing him to utter even a word on bended knees, yet the Holy Office, even before he had quitted Rome, inquired of the tribunal at Padua whether, in the action brought against Cesare Cremonini for certain philosophical indiscretions, there might not be something to compromise Galileo. A direct personal attack, inspired by an overweening zeal, quickly followed these early suspicions. On his return to Florence, Galileo took up his labors afresh in the pleasant solitudes of the Belvedere, placed at his service by the kind hospitality of the grand-duke; there he received his friends and pupils, who, on departing from these *conversaziones*, propagated his doctrines. At this a Dominican friar, Thomas Caccini, took umbrage, and, in a sermon delivered at Santa Maria Nuova on the miracle of Joshua, he suddenly exclaimed, "*Viri Galilæi, quid statis aspicientes in cœlum?*" The friar doubtless had heard of a conversation held at the court in presence of the grand-duchess dowager Christine of Lorraine, and the Archduchess Madeleine of Austria, in the course of which Father Castelli, a pupil of Galileo, had endeavored to prove, to the great satisfaction of his hearers, that one might believe in the earth's motion without questioning the authenticity of Joshua's miracle. Upon this subject Galileo addressed to his pupil a famous letter, in which he

precisely set forth the rights of science, at the same time asserting for religion its own. Here, according to him, are two separate domains, which are not rashly to be confounded.

"The Holy Scripture," said he, "can neither lie nor err, but it needs to be interpreted; for, were we to insist upon the literal sense of the words, we should find not only contradictions, but heresies and blasphemies; we should have to give to God hands, feet, ears, to suppose him subject to like passions with men—to anger, remorse, hatred; and, again, to hold that he forgets the past and is ignorant of the future. . . . Inasmuch as the Bible constantly requires interpretation to explain how very different the true sense of the words is from their apparent signification, it appears to me that it should be quoted in scientific discussions only as the last resort. In truth, Holy Scripture and Nature both come from the Divine Word, the one being the dictation of the Holy Ghost, while the other is the executor of God's decrees; but it was fitting that, in the Scriptures, the language should be adapted to the people's understanding in many things where the appearance differs widely from the reality. Nature, on the other hand, is inexorable and immutable; she is not at all concerned whether the hidden reasons and means through which she works are or are not intelligible to man, because she never oversteps the limit of the laws imposed upon her. Hence it appears that when we have to do with natural effects brought under our eyes by the experience of our senses, or deduced from absolute demonstrations, these can in no wise be called in question on the strength of Scripture texts that are susceptible of a thousand different interpretations, for the words of Scripture are not so strictly limited in their significance as the phenomena of Nature. . . . I therefore think it would be wise to forbid persons from using texts of Holy Scripture, and from forcing them, as it were, to support as true certain propositions in natural science, whereof the contrary may to-morrow be demonstrated by the senses or by mathematical reasoning."

This noble letter, the moderation of which would nowadays be admitted by every theologian, but which then gave out a dangerous odor of novelty, no doubt passed from hand to hand, was read by ill-disposed persons, perhaps fomented the agitation produced by Caccini's vehement assault, and furnished to another Dominican, Niccola Lorini, an opportunity of denouncing Galileo to the Congregation of the Holy Office. "Here," said the informer, "are propositions that seem to be suspect and rash, opinions that contradict the text of the Holy Scripture. Besides," he added, "Galileo and his disciples speak with little respect of the fathers of the Church, of St. Thomas of Aquino, and of Aristotle, whose philosophy has rendered so much service to the scholastic theology." The Inquisition, though search was made, was unable to procure the original of the letter, for Castelli had given it back to his master, and he prudently refused to part with it. The

inquisitors contented themselves with an examination of the copy sent by Lorini, in which they discovered a few ill-sounding phrases, but, on the whole, nothing clearly contradictory of the language of Scripture. Still they continued to note the words of Galileo; they questioned two Tuscan ecclesiastics about the speeches that he might have uttered in their hearing; they scrutinized the letters he had published on the subject of observing sun-spots.

Galileo, though quite ignorant of the strict watch kept on him by the Inquisition, had a vague apprehension of imminent danger. To ward it off, he adopted the expedient of going again to Rome in 1615, and of pleading his cause in person in the quarter where a successful defense was most to be desired. It has been asserted that Galileo was summoned before the bar of the Holy Office, but they who so assert are in error as to the date; it was not till a much later period, viz., the beginning of his second trial, that he was ordered to appear in Rome. On the present occasion he went of his own accord, no longer possessed of the fearless assurance with which he made his first journey, yet confidently hoping that he would disarm his opponents by the clearness of his explanations. Perchance he rested his expectation of convincing them as much upon the graces and charms of his wit, and the personal attractiveness which won for him all hearts, as upon the strength of his arguments.

Besides, he had taken more pains than even he did in 1611 to prepare the ground: he had, in urgent letters, rekindled the zeal of his friends, and had again obtained for himself all the external tokens of the official protection of the grand-duke. As before, he went down to the embassador's palace, the villa of the Trinità de' Monti, where now the Academy of France has its seat, and, the day after his arrival, went into the country. What with detailed explanations made in the presence of numerous auditors, keen and lively disputations in which he plainly showed the weakness of his opponents, frequent visits to distinguished personages, brief tractates in which he demonstrated the truth of the Copernican system, he omitted nothing that could influence in his own favor those currents of opinion which judges themselves cannot withstand.

Unfortunately for Galileo, the tribunal of the Inquisition was but little affected by external influences; it imposed laws on opinion, and took no advice from it. The members of the Holy Office, heedless of the steps taken by the illustrious astronomer, and of the ardor with which his ideas were espoused by a portion of Roman society, went on quietly with their work. In examining the letters on the sun-spots, they found therein two propositions worthy of censure. On the 24th of February, 1616, they unanimously pronounced it absurd and heretical to assert that the sun is motionless, and that the earth revolves. The sovereign pontiff immediately ordered Cardinal Bellarmin to summon Galileo, and to have him promise that he would no longer uphold

a proposition condemned by the Church. "If he refuses to obey," said the pontifical letter, "the Father Commissary, in the presence of a notary and witnesses, shall enjoin him absolutely to abstain from teaching that doctrine and that opinion, from upholding it or even speaking of it; in case he does not comply, he shall be cast into jail." Accordingly, on the 26th of February, 1616, Cardinal Bellarmin, in the presence of the commissary-general of the Holy Office and two witnesses, invited Galileo to renounce the two condemned propositions. After Bellarmin, the commissary-general again intimated to him, on behalf of the pope and the entire Congregation of the Holy Office, the formal order no longer to uphold, teach, and defend this opinion, whether by writing, by word of mouth, or in any manner whatsoever; if he failed to comply, he was to be prosecuted by the Holy Office. Galileo promised to obey.[1] On the 5th of March following, the Congregation of the Index condemned the work of Copernicus until it should be corrected.

From these authentic facts it results that a certain number of modern historians are deceived themselves, or would deceive us, when they insinuate that the Holy Office meant to condemn, not the system of Copernicus, but Galileo's theological interpretations of it. There was no question whatever about theological interpretations. In neither Copernicus's book, nor in the letters on the sun-spots, is there a word, a single phrase, in which the Holy Scriptures are interpreted. If here and there in his correspondence Galileo, out of respect to religion, endeavored to reconcile the data of science with the text of the Bible, he never published these explanations. It was not upon these private manuscript documents that he was tried, and the only document that furnished a basis for the charge was a printed work, purely scientific in character, and having nothing whatever to do with theology. By no manner of argumentation can the fact be negatived that a tribunal of theologians constituted itself a judge in a question of science, and decided it as an authority decides. The Holy Office did not forbid receiving and teaching the doctrine of Copernicus, on the ground that it was not yet demonstrated, as some of the apologists of the Holy See would have us believe; they would not permit it to be demonstrated; they pronounced it in advance to be "absurd, heretical, contrary to the text of the Scripture." Such is the whole truth about Galileo's first trial, and Domenico Berti sets it forth with much dialectic vigor.

II.

Galileo once reduced to silence by the act of submission to which he had subscribed, the object of the Inquisition was attained. No

[1] In a work entitled "Galileo Galilei und die Römische Curie" (Stuttgart, 1876), Herr von Gebler disputes the authenticity of the document which states these facts. Berti makes a victorious reply to him.

useless rigor followed the first procedure. Provided that the culprit spoke no more about the motion of the earth, the court of Rome would like nothing better than to make the most of a great mind that for a moment had gone astray, but whose genius and whose scientific fame were intact. After the trial, Galileo remained three months in Rome, and was kindly received by the sovereign pontiff. In fact, the rumor having spread that he had been punished by the Holy Office and obliged to retract and to do penance, he obtained from Cardinal Bellarmin a certificate to the contrary effect. All that was done, said the cardinal, was to forbid him defending or upholding the system of Copernicus. What advantage could it have been to drag Galileo down from the high position he occupied in the world's opinion? It was enough, for the purposes of his judges, if they could shut his mouth.

In this they supposed they had succeeded, but here they failed to take account of the overmastering impulse to propagate truth, which is the very essence of scientific genius. Galileo could neither erase from his mind a belief that rested on a demonstration, nor refuse to employ it in advancing to fresh discoveries, nor abstain from speaking of it with those who consulted him with regard to their own astronomical labors, or took an interest in his. In his retirement at the Belvedere, where, since his return from Rome, he led a more secluded life than ever, he received, as in former times, numerous visits, nearly all prompted by the love of science. He was still the recognized and admired head of the scientific movement in Italy. Why should he not converse about the cardinal proposition of the earth's motion with the young *savants* who came to ask his advice and to receive his instruction? A distinguished Italian narrates how, having spent a few days with him, after the close of his first trial, he heard from Galileo's mouth the exposition of the Copernican system, was converted to his ideas, and himself then converted Campanella to that doctrine.

Hence the submission of Galileo was only apparent. Later he was justly charged with having broken his promise. Still, he avoided compromising himself publicly, and in his first work, "Il Saggiatore," which is a model of keen, clever irony, he hardly ventured to write anything touching on the system of Copernicus. Presently the election of a new pontiff inspired him with the hope that the court of Rome might relax its rigor. Urban VIII., of the family of Barberini, was a Florentine, a lover of letters, well disposed toward the Academy of the Lincei, and especially friendly to Galileo, to whom he had addressed, while yet a cardinal, some verses conceived in a vein of eulogy. Galileo went to Rome to see him, had six long audiences with him, was presented by him with a picture, medals, *agnus deis*, and a pension for his son, and doubtless talked with him about the great subject which filled his mind. We can only guess at what was

said by the two friends: some authors assert that Urban VIII. then inclined toward the Copernican system; others, on the contrary, say that he demonstrated to Galileo the impossibility of maintaining the theory of the earth's motion. The truth is, that we know nothing about the matter; neither the pope nor the astronomer has given out anything about the nature of their conversations. Perhaps even, as we shall shortly see, they believed that they could agree, while differing from one another widely.

At all events, it seems that, dating from the accession of Urban VIII. to the pontifical throne, Galileo felt more free to touch anew upon the forbidden subject, under a different form. Was this the result of an overweening confidence in the friendship of the sovereign pontiff, of a too favorable interpretation of some friendly speeches, or of the impossibility of being silent while Kepler was speaking boldly outside of Italy, while on Italian soil one was constantly harassed by ignorant opponents, and, though one's hand were full of truths, one durst not open it and rout them. The "Dialogues on the Two Great Systems of the Universe," which were destined to bring Galileo into so much trouble, show that, in writing them, he stood between the conflicting influences of a strong desire to speak and the fear of compromising himself. He rather insinuates his ideas with true Italian finesse than puts them forth boldly. He does not defend the Copernican system, but expounds it. He even takes the precaution of stating, in a preface, the rough draft of which had been sent to him from Rome, that the true aim of his work is to show that in Italy ideas are not condemned unknown, and that nowhere is this delicate matter better understood than in Italy. He carefully avoids drawing conclusions: the personage whom he introduces as the representative of the doctrine of Ptolemy and as the defender of the belief in the earth's immobility, though clad in the strongest dialectical coat of mail, and though driven to his last ditch by the keen raillery and the copious logic of his interlocutors, replies to them unmoved: "Your arguments are the most ingenious that can be conceived, but I consider them to be neither true nor conclusive." Father Riccardi, Master of the Sacred Palace, whose business it was to examine Galileo's manuscript, suffered himself to be half-way won by these exhibitions of innocence, and gave a permit for the work to be printed, though not without resistance. He afterward protested that he had been deceived by the author, and that some of the conditions on which he had granted the *imprimatur* were not fulfilled. At first it was agreed that the "Dialogues" should be printed at Rome; but at the earnest entreaty of Galileo leave was granted to have the work done at Florence, where it would involve less trouble and cost to him, and where, above all, he could more easily evade the surveillance of the Sacred Palace. In this negotiation Galileo displayed a fecundity of resource and a force of will that show how

important he considered the publication of his work to be. The chief fruit of his address was that he escaped a second revision of the text, which would have been made at Rome had the work been printed there. Galileo chose rather to deal with the inquisitor at Florence, to whom Father Riccardi had delegated his powers, but who, doubtless at the solicitation of the grand-duke, exercised these powers with less rigor than would have been used at the Sacred Palace. We can imagine the wrath manifested by the court of Rome; in fact, despite all its finesse, it had been outwitted by an Italian shrewder even than itself, by a fellow-countryman of Macchiavelli.

Would Galileo have been so eager for the publication of his work, if he had foreseen the dangers to which he exposed himself by publishing it? The sovereign pontiff, immediately upon receipt of the book, in the beginning of August, 1632, was highly incensed, charged Galileo with having made an unhandsome return for his kindness, and would on the spot have referred the author and the book to the tribunal of the Holy Office, had he not been restrained by the importunities of the embassador Niccolini, and his fear of offending the Grand-duke of Tuscany. "Galileo," said Urban, "has not acted without deliberation, has not sinned through ignorance; he was perfectly well aware of the difficulties of the case, for I myself have made them clear to him." These expressions of dissatisfaction on the part of the sovereign pontiff would seem to show that, in the interviews of which we have spoken, the two friends had touched on the delicate question of the earth's motion, and that, by a process of self-illusion quite natural under the circumstances, each had supposed he had convinced the other. The pope was angry at Galileo, as at one in whom he had for a long time mistakenly reposed confidence—as though a fraud had been practised upon him; this feeling, which had broken the bond of their old friendship, explains the harshness with which Urban treated the friend of his youth. Nor had Galileo been less mistaken with regard to the disposition of the pope's mind. He flattered himself that he should find in him an indulgent judge of his astronomical theories, while in point of fact he was wounding Urban in his most sacred convictions. Had he known that the pope was so opposed to the system of Copernicus, doubtless he never would have braved the wrath of one whose power was unlimited, or affronted a tribunal from which there was no appeal.

On receipt of the "Dialogues," Urban instructed a commission to examine the book and report to him. As soon as the report came into his hands, he commanded the inquisitor at Florence to communicate to Galileo a formal summons to appear in October before the commissary-general of the Holy Office in Rome. Galileo, then seventy years of age, and suffering from hernia, asked the authorities to take into consideration his age and his malady, and to dispense him from the journey. The Grand-duke of Tuscany interceded for him. But

Urban would listen to nothing; fearing lest he should be deceived, as he believed he had been before, he would permit no delay. He would not even believe the testimony of three physicians who attested the reality of Galileo's malady; he sent the inquisitor in person to him, with orders to arrest and bring him in irons to Rome, if he was found to be in a condition to bear the journey. Poor Galileo had taken to his bed, and, as was said by one of his friends, "he was more in danger of going to the other world than to Rome." He was not in a condition to be removed until January, 1633. The good offices of the Grand-duke of Tuscany attended him to the presence of his judges, and there the friendship of Niccolini accompanied him—weak succors these in the face of such powerful adversaries. At first the embassador's palace was appointed as his place of confinement, and he was commanded not to leave it; he went out only in order to submit to the interrogatories proposed to him by the Holy Office.

On the 12th of April he was interrogated for the first time. To begin with, he was asked if he remembered what took place in 1616, when he had to appear before Cardinal Bellarmin and the commissary-general of the Holy Office. Galileo admitted having heard it declared on that day that the system of Copernicus could not be maintained or defended, as being contrary to the Holy Scriptures. "It may be," he added, "that at the same time I myself was forbidden to maintain or defend that opinion, but I do not recollect, it is now so long ago." Whatever may be the interest now taken in a case so bound up with the question of the freedom of thought, it is not easy to believe with Berti that Galileo replied to this first interrogatory with entirely good faith. When a prohibition is issued in terms so formal as those we have given, upon so definite a point, neither the form nor the substance is ever forgotten. Ambiguity was out of the question after Bellarmin's warning, and still more after the solemn injunction of the commissary-general. Domenico Berti is in error with regard to the psychological conditions of memory where he says that it must have been easier for Galileo to recollect the conciliatory words of Cardinal Bellarmin than the threats of the commissary-general. On the contrary, what strikes one most under such circumstances, what impresses itself deepest in the memory, is the threats. How could any one forget words so simple, so clear, so menacing, as these: "You are forbidden to maintain this opinion, to teach or to defend it, whether by writing or by word of mouth, or in any other manner whatsoever, else the Holy Office will take information against you!" These last words in particular must have buried themselves like an arrow in the memory of Galileo, nevermore to come out. He knew all too well what he had to fear from the Inquisition ever to forget on what conditions that tribunal agreed to take no further cognizance of him. The silence he kept in public for sixteen years upon the forbidden subject, and even the care he took in his "Dialogues" to give to his thoughts an in-

offensive turn, might serve as evidence of the faithfulness of his memory.

The fact is, that the reason of Galileo's taking up his pen again to treat a forbidden subject was not that he had forgotten the formal prohibition. He might have made answer, with great frankness, that, though he had been ordered to hold his peace, yet he had not been convinced, and that, after so many years of silence, the need of proclaiming the truth had more power over him than the fear of disobeying. But it was not for a mind so subtile, nor for a character so wary as that of Galileo, to be tied down to a categorical declaration, and so to shut every portal of escape. He chose rather to use evasions with his judges, to plead extenuating circumstances, to produce the impression that he might have misunderstood, but that he had not acted with evil intent and with his eyes open. Even while undergoing the first interrogatory, he was still in hopes of finding in the sovereign pontiff some remnant of friendship, or, at least, of good-will; and this was another reason why he made an evasive reply, and did not compromise himself by an explicit admission of his offenses. He appears to have believed, at this first session, that it would be possible for him to have a private interview with the holy father. Being questioned as to what had been said to him by Cardinal Bellarmin in 1616, he replied that some of the details of their conversation he could intrust only to the ear of the sovereign pontiff. This plainly was a request for an interview with Urban. His judges seemed not to understand him, or, if they carried his words to the holy father, they obtained from him no favorable answer; but, in the course of the trial, it became evident that Galileo could expect neither indulgence nor commiseration from his old friend.

All of Galileo's answers at the first interrogatory present the same character of ambiguity. On being asked whether, before he begged of Father Riccardi license to print his "Dialogues," he had informed the master of the Sacred Palace of his having previously been forbidden to treat certain subjects, his reply was that he had not mentioned that to Father Riccardi, "for he did not think it necessary to do so, having no scruples, nor having supported or defended in his book the opinion of the earth's motion and the stability of the sun." It is not altogether certain that, by thus altering the truth, Galileo chose the best line of defense; probably a little more of frankness would have served him better. He was simply trifling with his judges and taking them for fools, when he tried to make them believe that, in his "Dialogues," his purpose had been to demonstrate the "weakness and insufficiency" of Copernicus's arguments. The disguises in which the author clothes his thoughts fail to deceive the thoughtful reader. Throughout the work, the defender of Ptolemy's theory, Simplicio (in whom it has been wrongfully supposed that some of the traits of Urban VIII. may be found), is overthrown by his opponents'

arguments, and made an object of ridicule by their irony. Surely, it was imprudent on the part of Galileo to deny the evidence, thus giving to his defense the appearance of double-dealing.

Nor did the resort to this course deceive any one. The three judges who had questioned him unanimously declared that in his book he had contravened the injunctions of Cardinal Bellarmin, and the decree of the Congregation of the Index. Two of them added that he was gravely suspect of adhering to the doctrine of Copernicus. After the close of his first interrogatory, he was removed to the palace of the Holy Office, and there he occupied a chamber in the sleeping-apartments of the wardens, with an express prohibition of going out without leave. Here he had long and frequent interviews with Father Vincenzo Macolano, commissary of the Holy Office, an educated man of kindly disposition, and a friend of the grand-duke and of the Tuscan embassador; Father Macolano took it upon himself to warn Galileo of the dangers of the situation, and to aid him with his counsels. First of all, he induced Galileo to submit without reserve, to admit his offenses, and to repent. "I made his error patent to him," wrote the father commissary, at the close of one of their interviews; "he clearly saw that he had made a mistake, that in his book he had gone too far, and he expressed to me his regret in words full of feeling, as though he drew comfort from the knowledge of his error, and was thinking of confessing it judicially; he only asked of me a little time to consider how he might best word his confession." Father Macolano then looked for a speedy ending of the trial, and a less severe sentence. "When once we have Galileo's confession," said he, "the reputation of the tribunal will be safe, and the accused can be treated with indulgence." Evidently he expected that the case would not be carried beyond the first stage of inquisition, and that it would terminate by a special form of interrogatory, known as the "interrogatory with regard to the intention."

If things were pushed further than the commissary of the Holy Office either wished or expected, the blame does not rest with the accused, who, once warned, immediately resolved to submit. On being interrogated again on the 30th of April, Galileo confessed that, without meaning it, he had presented too forcibly the arguments in favor of the system of Copernicus, his intention all the while being to refute them, and that thus he might have led the public into error. He declared that he was "ready to refute the opinion of Copernicus by all the most efficacious methods that God might place within his power." These words, no doubt dictated to him by the humanity of the father commissary, had the effect of procuring for him some measure of liberty. That very evening he was sent back to the palace of the Tuscan embassador, so that there he might receive such care as the state of his health required.

We must not forget that to the humiliation of repudiating his

most cherished opinions, of belying his own thoughts, and of seeing himself treated as a criminal after he had, by his labors, done honor to his country and to mankind, were added physical sufferings of the most grievous kind. It is impossible to read without emotion the appeal he addressed to his judges at the end of his written defense: "It remains for me to urge one final consideration, viz., the pitiable state of bodily indisposition to which I have been reduced by incessant mental agony during ten whole months, together with the hardships of a long and toilsome journey, in the most inclement weather, at the age of threescore years and nine. . . . I confide in the mercy and goodness of the most eminent seigniors who are my judges, and I hope that if, in the integrity of their justice, they think that so great sufferings lack anything to make them equal to the punishment that my offenses deserve, they will be pleased, at my entreaty, to remit the difference in consideration of the failing strength of my old age, which I humbly commend to them."

Among the hitherto unpublished documents contained in Berti's work there is one that is of the highest importance. This is a summary of the case, giving an enumeration not only of what was decreed but also of what was done. After reading a text so clear and so unambiguous on all points save one, while on that one it agrees perfectly with other authentic documents, we no longer find ground for supposing it was only on paper that Galileo was threatened with the torture, and forced to make abjuration. A decree of the pope, dated June 16th, ordains that instead of a simple "examination as to intention," such as the commissary of the Holy Office had expected, an interrogatory [1] should be had with the threat of torture, if the accused could stand it; he is ordered to make abjuration, and condemned to imprisonment according to the good pleasure of the congregation. This decree was not, as has been supposed, a simple declaration designed to sustain the reputation of the tribunal for severity, while the culprit was treated leniently; on the contrary, it was executed literally, as is shown by the agreement of the documents concerning this portion of the trial.

On being interrogated for the last time on the 21st of June, Galileo was ordered to state whether he then held or ever had held the opinion that the sun is the centre of the world and that the earth moves. He humbly replied that ever since the decree of the Congregation of the Index, in 1616, he had always held and still did hold the opinion of Ptolemy to be "most true and unquestionable." This reply not appearing to be satisfactory, the father commissary insisted on knowing the truth, and wound up by declaring that, if the whole truth were not stated, recourse would be had to torture. "I am here in

[1] Author's Note.—We interpret three obscure words in the pontifical decree, *ac si sustinuerit*, in the sense given to them by Berti. Th. Henri Martin gives a different translation, not without good reasons. The matter is one that will bear discussion. It is still undecided, even after the publication of the documents.

order to obey," replied Galileo, with some show of terror. The text of the sentence shows that he was treated more rigorously yet. "Inasmuch as it appears to us that you have not told the whole truth as touching your intention, we have deemed it necessary to resort to the *examen rigorosum*." Now, in the language of the Inquisition, *examen rigorosum* means just the torture and that alone: it is the law-term approved by jurists and regularly employed in sentences which condemn the accused to the cruel punishment of the *strappado*. "In case the accused," say the treatises on inquisitorial law, "does not clear himself of the charges, recourse is to be had to the *examen rigorosum*, torture having been devised to supply the want of witnesses." In two manuscripts of the first half of the seventeenth century, both of them relating to the forms of procedure of the Holy Office, the expression *examen rigorosum* is pointed out as the formula to be employed by judges in ordering the application of torture.

From the text of the sentence, from the pontifical decree already quoted, and from the summary of the acts of the trial, we might infer that Galileo was actually subjected to torture, if among the documents we found the official record (*procès-verbal*) of the *examen rigorosum*, as we find the official record of the previous examinations. The rule of the Inquisition was ever the same: the notary or registrar of the Holy Office was present at all interrogatories, and took down carefully the words of the sufferer; all the details of the *examen rigorosum* were recorded in a register, from the first intimation to the accused that he was to be taken to the place of punishment, down to the moment when he was released from the torture. On looking over the records of these dread sessions, we find all the words spoken by the sufferer while his clothes are being taken off and while he is being tied to the instrument of torture; all the replies he makes to his judges, all his pleas; every movement he makes is noted with cold precision, nay, even his sighs, his groans, while under the torture. "He was hoisted by the rope," calmly writes the notary, "and while suspended he would cry out in a loud voice, 'O Lord God, have pity! O Our Lady, help me!' repeating these words again and again. Then he was silent, and having for a little while thus held his peace, he began again to cry out, 'O God, O God!'"

If Galileo had been subjected to this mode of trial, the *procès-verbal* of the proceedings would certainly have been preserved along with the other records of the case. But, then, might not the *examen rigorosum* have taken place in the absence of the registrar; or might not the registrar, though he was present, have omitted to make a record? Both of these suppositions appear to be equally inadmissible, for they are in flat contradiction to all the precedents and all the rules of the tribunal. Neither can we suppose that the agent of the Holy Office suppressed the *procès-verbal* of the torture in order that both he and his principals might escape the indignation of posterity.

This were gratuitously to transform an obscure, an irresponsible personage into an humanitarian philosopher who is ages ahead of the thought of his time and who purposely destroys a sorrowful page of history. The most probable account of what took place would be this: According to all the treatises on inquisitorial law, the commissary was authorized not to inflict torture on aged men, or on persons suffering from disease, who might die under the punishment. The advanced age of Galileo, and his infirmities, aggravated as they were by so much mental suffering, naturally placed him in the category of culprits who were not subjected to torture. If he was spared that dreadful infliction, Berti gives all the credit to the humanity of the father commissary; he even appears to think that, but for the kindly intervention of Father Macolano, the sovereign pontiff and the Congregation of the Holy Office would have given over Galileo to the executioner.

Let us be more fair. It would be a libel on Urban VIII. to represent him as thirsting for the blood and pleased with the sufferings of his old friend. The pontifical decree of June 16th has this important proviso regarding the employment of torture, that it should not be used unless the accused could endure it. When he expressed himself thus, the sovereign pontiff was perfectly well aware that Galileo could not stand such a trial, and he consented beforehand, without needing to be entreated by the commissary, to the omission of the torture. What, indeed, would have been the use of such extreme rigor? Urban did not desire the death of the culprit; he wanted to make certain that Galileo would never more speak or write about the question of the earth's motion; and it was in order to so strike him with terror as to insure his silence that of all the agonies of the trial he saved him only from the last—the only one that would have been of no use. The pope was not so cruel as Berti thinks, but neither did he give any sign of that compassion and indulgence toward the accused with which he is too often credited. This point is worth repeating, inasmuch as it is the clearest result of Berti's publication: the various phases of the trial of Galileo were not arranged with a view to theatrical effect, and to make an outward show of great severity, so as to intimidate the adherents of Galileo's doctrine, while, behind the scenes, the culprit was treated with kindness. The threat of torture, the abjuration, the sequestration, were realities, and not, as has been supposed, simply monitions addressed to overbold men of science. At first, the court of Rome did not concern itself so much about impressing the imagination of the public as about striking Galileo. Here was a rebellious subject who had once before been treated with the greatest lenience, but who repaid the indulgence of the Holy Office with the transparent irony of his "Dialogues;" who had set snares for the person appointed to examine his manuscript; who, at his first interrogatory, had made sport of his judges, nay, perhaps of the sovereign pontiff himself: he must now be reduced to silence for

good and all, by conducting him, through a series of moral tortures, to the uttermost limits of terror.

At the same time the solemn form of his abjuration was calculated to prevent him from ever again inclining toward the Copernican doctrine. How could he embrace that doctrine again after he had openly pronounced it heretical, and promised, as he was compelled to do, to inform upon all persons suspected of this heresy? His judges, however, were not yet satisfied; he was feared even after his abjuration. He was confined at first in the palace of the Archbishop Piccolomini, at Siena, then at his own villa of Arcetri, near Florence, with leave to receive a few visits of relatives and friends, but on condition that several persons should never meet there to hold conversation. It was particularly feared that he would communicate with learned men abroad and in Italy. Father Castelli, his old pupil, in vain begged leave to see him, though he promised not to talk with him about the earth's motion. In order to protect all other Catholic countries against the contagion of his ideas, the pope dispatched to all apostolic nuncios and to all inquisitors copies of the sentence pronounced on Galileo, and of his act of abjuration. At Florence his chief disciples and friends, especially the professors of mathematics, were summoned by name to listen to the reading of these two documents.

In shutting the mouth of a writer so gifted, so full of resources, so admired by the public, it was hoped that an end was made of the doctrine of Copernicus—that dangerous doctrine which alarmed the theologians by displacing the centre of the universe, ousting the earth from its primacy and substituting the sun, and opening the way for hypotheses of the plurality of worlds and the end of creation. But the effort was vain. The theory of the earth's motion has survived all condemnations. It was not Galileo, as tradition would have it, that uttered the famous saying, "*Eppur si muove*," but the general voice of mankind who, after his death, thus proclaimed the undying truth of his belief.

Here we will stop. We would not weaken, by any comments of ours, the importance of the documents we have been examining. It is a fixed historical fact that in the beginning of the seventeenth century the Roman congregations, assuming to represent the Church, and not disavowed by her, made themselves the judges of a scientific question, and decided it in a way contrary to the conclusions of science. The splendor of Galileo's genius and the commiseration inspired by his sufferings impress upon this discussion a tragical and popular character; but the emotion produced by his cruel fate must not blind us to the gravity of the problem. The great question was whether, in countries that were then Catholic and destined so to remain, Science could free herself from the dominion of Faith. The trial of Galileo, so far from retarding this conclusion, as is commonly supposed, on the contrary made it inevitable and urgent. So soon as the

court of Rome saw how unwisely she had acted in deciding a question beyond her competence, thus laying herself open to the danger of being the next day convicted of error, it became her interest, no less than the interest of Science, to distinguish clearly between the two domains, Science and Faith. If, nowadays, she avoids entering into scientific controversies, it is because she has been taught by experience that a decision might compromise her. Her authority could hardly stand after a second edition of the sentence in which she once forbade the sun to stand still and the earth to revolve.

DISTANCE AND DIMENSIONS OF THE SUN.

By Professor C. A. YOUNG,
OF DARTMOUTH COLLEGE.

THE problem of finding the distance of the sun is one of the most important and difficult presented by astronomy. Its importance lies in this, that this distance—the radius of the earth's orbit—is the base-line by means of which we measure every other celestial distance, excepting only that of the moon; so that error in this base propagates itself in all directions through all space, affecting with a corresponding proportion of falsehood every measured line—the distance of every star, the radius of every orbit, the diameter of every planet.

Our estimates of the masses of the heavenly bodies also depend upon a knowledge of the sun's distance from the earth. The quantity of matter in a star or planet is determined by calculations whose fundamental data include the distance between the investigated body and some other body whose motion is controlled or modified by it; and this distance generally enters into the computation by its cube, so that any error in it involves a more than threefold error in the resulting mass. An uncertainty of one per cent. in the sun's distance implies an uncertainty of more than three per cent. in every celestial mass and every cosmical force.

Error in this fundamental element propagates itself in time also, as well as in space and mass. That is to say, our calculations of the mutual effects of the planets upon each other's motions depend upon an accurate knowledge of their masses and distances. By these calculations, were our data perfect, we could predict for all futurity, or reproduce for any given epoch of the past, the configurations of the planets and the conditions of their orbits, and many interesting problems in geology and natural history seem to require for their solution just such determinations of the form and position of the earth's orbit in by-gone ages.

Now, the slightest error in the data, though hardly affecting the result for epochs near the present, leads to uncertainty which accumulates with extreme rapidity in the lapse of time; so that even the present uncertainty of the sun's distance, small as it is, renders precarious all conclusions from such computations when the period is extended more than a few hundred thousand years from the present time. If, for instance, we should find as the result of calculation with the received data that two millions of years ago the eccentricity of the earth's orbit was at a maximum, and the perihelion so placed that the sun was nearest during the northern winter (a condition of affairs which it is thought would produce a glacial epoch in the southern hemisphere), it might easily happen that our results would be exactly contrary to the truth, and that the state of affairs indicated did not occur within half a million years of the specified date—and all because in our calculation the sun's distance, or solar parallax by which it is measured, was assumed half of one per cent. too great or too small. In fact, this solar parallax enters into almost every kind of astronomical computations, from those which deal with stellar systems and the constitution of the universe to those which have for their object nothing higher than the prediction of the moon's place as a means of finding the longitude at sea.

Of course, it hardly need be said that its determination is the first step to any knowledge of the dimensions and constitution of the sun itself.

This parallax of the sun is simply *the angular semi-diameter of the earth as seen from the sun;* or, it may be defined in another way as the angle between the direction of the sun ideally observed from the centre of the earth, and its actual direction as seen from a station where it is just rising above the horizon.

We know with great accuracy the dimensions of the earth. Its mean equatorial radius, according to the latest and most reliable determination (agreeing, however, very closely with previous ones), is 3962.720 English miles [6377.323 kilometres], and the error can hardly amount to more than $\frac{1}{100000}$ of the whole—perhaps, 200 feet one way or the other. Accordingly, if we know how large the earth looks from any point, or, to speak technically, if we know the parallax of the point, its distance can at once be found by a very easy calculation: it equals simply [206,265[1] × the radius of the earth] ÷ [the parallax in seconds of arc].

Now, in the case of the sun it is very difficult to find the parallax with sufficient precision on account of its smallness—it is less than 9″, almost certainly between 8.8″ and 8.9″. But this tenth of a second

[1] This number 206,265 is the length of the radius of a circle expressed in seconds of its circumference. A ball one foot in actual diameter would have an apparent diameter of one second at a distance of 206,265 feet, or a little more than 39 miles. If its apparent diameter were 10″, its distance would, of course, be only $\frac{1}{10}$ as great.

of doubtfulness is more than $\frac{1}{100}$ of the whole, although it is no more than the angle subtended by a single hair at a distance of nearly 800 feet. If we call the parallax 8.86″, which is probably very near the truth, the distance of the sun will come out 92,254,000 miles, while a variation of $\frac{1}{20}$ of a second either way will change it nearly half a million of miles.

When a surveyor has to find the distance of an inaccessible object, he lays off a convenient base-line, and from its extremities observes the directions of the object, considering himself very unfortunate if he cannot get a base whose length is at least $\frac{1}{10}$ of the distance to be measured. But the whole diameter of the earth is less than $\frac{1}{11000}$ of the distance of the sun, and the astronomer is in the predicament of a surveyor who, having to measure the distance of an object ten miles off, finds himself restricted to a base of less than five feet, and herein lies the difficulty of the problem.

Of course, it would be hopeless to attempt this problem by direct observations, such as answer perfectly in the case of the moon, whose distance is only thirty times the earth's diameter. In her case, observations taken from stations widely separated in latitude, like Berlin and the Cape of Good Hope, or Washington and Santiago, determine her parallax and distance with very satisfactory precision; but if observations of the same accuracy could be made upon the sun (which is not the case, since its heat disturbs the adjustments of an instrument), they would only show the parallax to be somewhere between 8″ and 10″, its distance between 126,000,000 and 82,000,000 miles.

Astronomers, therefore, have been driven to employ indirect methods based on various principles: some on observations of the nearer planets, some on calculations founded upon the irregularities—the so-called perturbations—of lunar and planetary movements, and some upon observations of the velocity of light. Indeed, before the Christian era, Aristarchus of Samos had devised a method so ingenious and pretty in theory that it really deserved success, and would have attained it were the necessary observations susceptible of sufficient accuracy. Hipparchus also devised another founded on observations of lunar eclipses, which also failed for much the same reasons as the plan of Aristarchus.

The idea of Aristarchus was to observe carefully the number of hours between new moon and the first quarter, and also between the quarter and the full. The first interval should be shorter than the second, and the difference would determine how many times the distance of the sun from the earth exceeds that of the moon, as will be clear from the accompanying figure. The moon reaches its quarter, or appears as a half-moon, when it arrives at the point Q, where the lines drawn from it to the sun and earth are perpendicular to each other. Since the angle H E Q = E S Q, it will follow that H Q is the same fraction of H E as Q E is of E S; so that, if H Q can be found,

we shall at once have the ratio of Q E and E S. Aristarchus thought he had ascertained that the first quarter of the month (from N to Q) was about 12 hours shorter than the second, from which he computed the sun to be about 19 times as distant as the moon. The difficulty

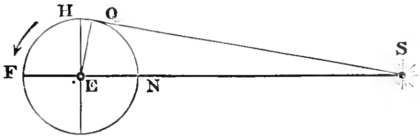


FIG. 1.

lies in the impossibility of determining the precise moment when the disk of the moon is an exact semicircle. The real difference between the first and second quarters is really not quite 36 minutes, and the sun's distance is about 400 times the moon's.

The different methods upon which our present knowledge of the sun's distance depends may be classified as follows:

1. Observations upon the planet Mars near opposition, in two distinct ways:
   (*a*) Observations of the planet's declination made from stations widely separated in latitude.
   (*b*) Observations from a single station of the planet's right ascension when near the eastern and western horizons — known as Flamsteed's method.
2. Observations of Venus at or near inferior conjunctions:
   (*a*) Observations of her distance from small stars measured at stations widely different in latitude.
   (*b*) Observations of the transits of the planet: 1. By noting the *duration* of the transit at widely-separated stations; 2. By noting the true Greenwich time of contact of the planet with the sun's limb; 3. By measuring the distance of the planet from the sun's limb with suitable micrometric apparatus; 4. By photographing the transit, and subsequently measuring the pictures.
3. By observing the oppositions of the nearer asteroids in the same manner as those of Mars.
4. By means of the so-called parallactic inequality of the moon.
5. By means of the monthly equation of the sun's motion.
6. By means of the perturbations of the planets, which furnish us the means of computing the ratios between the *masses* of the planets and the sun, and consequently their distances—known as Leverrier's method.
7. By measuring the velocity of light, and combining the result (*a*) with equation of light between the earth and sun, and (*b*) with the constant of aberration.

Our scope and limits do not, of course, require or allow any exhaustive discussion of these different methods and their results, but some of them will repay a few moments' consideration:

The first three methods are all based upon the same general idea, that of finding the actual distance of one of the nearer planets by ob-

serving its displacement in the sky as seen from remote points on the earth. The *relative* distances of the planets are easily found in several different ways,[1] and are known with very great accuracy—the possible error hardly reaching the ten-thousandth in even the most unfavorable cases. In other words, we are able to draw for any moment an exceedingly accurate map of the solar system—the only question being as to the scale. Of course, the determination of any line in the map will fix this scale; and for this purpose one line is as good as another, so that the measurement of the distance from the earth to the planet Mars, for instance, will settle all the dimensions of the system.

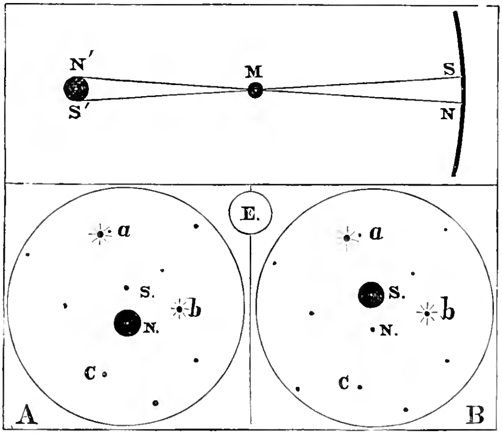


Fig. 2.

The figure illustrates the method of observation. Suppose two observers, situated one near the north pole of the earth, the other near the south. Looking at the planet, the northern observer will see it at *N* (in the upper figure), while the other will see it at *S*, farther north in the sky. If the northern observer sees it as at *A* (in the lower part of the figure), the southern will at the same time see it as at *B*; and, by measuring carefully at each station the apparent distance of the planet from several of the little stars (*a*, *b*, *c*) which appear in the field of view, the amount of the displacement can be accurately ascertained. The figure is drawn to scale. The circle *E* being taken to represent the size of the earth as seen from Mars when nearest us, the black disk represents the apparent size of the planet on the same scale, and the distance between the points *N* and *S*, in either figure *A* or *B*, represents, on the same scale also, the displacement which would

[1] One method of determining the relative distances of a planet and the sun from each other and from the earth is the following, known since the days of Hipparchus: First, observe the date when the planet comes to its opposition—i. e., when sun, earth, and planet, are in line, as in the figure, where the planet and earth are represented by *M* and *E*. Next, after a known number of days, say one hundred, when the planet has advanced

be produced in the planet's position by a transference of the observer from Washington to Santiago, or *vice versa.*

The first modern attempt to determine the sun's parallax was made by this method in 1670, when the French Academy of Sciences sent Richer to Cayenne to observe the opposition of Mars, while Cassini (who proposed the expedition), Roemer, and Picard, observed it from different stations in France. When the results came to be compared, however, it was found that the planet's displacement was imperceptible by their existing means of observation: from this they inferred that the planet's parallax could not exceed half a minute of arc, and that the sun's could not be more than 10″.

In 1752 Lacaille at the Cape of Good Hope made similar observations, and their comparison with corresponding observations in Europe showed that instruments had so far improved as to make the displacement quite sensible. He fixed the sun's parallax at 10″, corresponding to a distance of about 82,000,000 miles.

In more recent times the method has been frequently applied, and with results on the whole satisfactory. In 1849–'52 Lieutenant Gilliss was sent by the United States Government to Santiago, in Chili, to observe both Mars and Venus in connection with northern observatories. In 1862 a still more extended campaign was organized, in which a great number of observatories in both hemispheres participated. Prof. Newcomb's careful reduction of the work puts the resulting parallax at 8.855″. The method can be used to the best advantage, of course, when at the time of opposition the planet is near its perihelion and the earth near its aphelion; these favorable oppositions occur about once in fifteen years, and the one which is next to occur, in September, 1877, is so exceptionally advantageous that already somewhat extensive preparations are on foot to secure its careful and general observation.

to M and the earth to E,′ observe the planet's elongation from the sun, i. e., the angle $M' E' S$. Now, since we know the periodic times of both the earth and planet, we shall know both the angle $M S M'$ moved over by the planet in one hundred days, and also $E S E$ described in the same time by the earth, the difference is $M' S E$,′ called by some

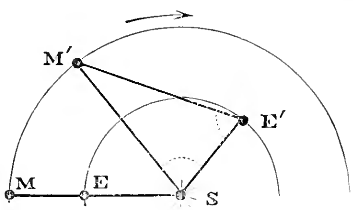


Fig. 3.

writers the synodic angle. We have, therefore, in the triangle $M' S E$,′ the angle at E' measured, and the angle $M' S E'$ known as stated above; this of course gives the third angle at M,′ and hence we know the *shape* of the triangle, and by the ordinary processes of trigonometry can find the relative values of its three sides.

In observations of this sort upon Mars or the asteroids, the position and displacement of the planet, as seen from different stations, are determined by comparing it with neighboring stars. When Venus, however, is nearest us, she can be observed only by day, so that in her case star comparisons are as a general thing out of the question. But occasionally at her inferior conjunction she passes directly across the disk of the sun, and her parallactic displacement from different stations can then be determined by making any such observations as will enable the computer to ascertain accurately her apparent distance and direction from the sun's centre at some given moment. Gregory in 1663 first pointed out the utility of such observations for ascertaining the parallax, but it was not until some fifteen years later that the attention of astronomers was secured to the subject by Halley, who discussed the matter thoroughly, and showed how the problem might be solved with accuracy by observations such as were entirely practicable even by the instruments and with the knowledge then at command. In 1761 and 1769 two transits occurred which were observed in all accessible quarters of the globe by expeditions sent out by the different governments. From different sets of these observations variously combined by different computers, values of the solar parallax were obtained ranging all the way from 7.5″ to 9.2″. A general discussion of all the materials afforded by the two transits was first made by Encke in 1822, and he obtained, as the most probable result, the value 8.″5776, which from that time for more than thirty years was accepted by all astronomers as the best attainable approximation to the truth. In order to harmonize the results, however, he thought himself obliged to reject the observations of several stations. In 1854 Hansen, in publishing some of his results respecting the motion of the moon, announced that Encke's value of the solar parallax could not be reconciled with his investigations; within the next six or seven years several independent researches by other astronomers confirmed his conclusions, and the most recent recomputations show that the observations rejected by Encke are as trustworthy as any, and that the errors of observation were so considerable in 1769 that nothing more can be fairly deduced from that transit than that the solar parallax is probably somewhere between 8.7″ and 8.9″.

The method of observation then used consisted simply in noting the moment when the limb of the planet came in contact with that of the sun—an observation which is attended with much more difficulty and uncertainty than would at first be supposed. The difficulties depend in part upon the imperfections of optical instruments and the human eye, partly upon the essential nature of light, leading to what is known as diffraction, and partly upon the action of the planet's atmosphere. The two first named causes produce what is called irradiation, and operate to make the apparent diameter of the planet, as seen on the solar disk, smaller than it really is—smaller, too, by an

amount which varies with the size of the telescope, the perfection of its lenses, and the tint and brightness of the sun's image. The edge of the planet's image is also rendered slightly hazy and indistinct.

The planet's atmosphere also causes its disk to be surrounded by a narrow ring of light, which becomes visible long before the planet touches the sun, and at the moment of internal contact produces an appearance of which the accompanying figure is intended to give an

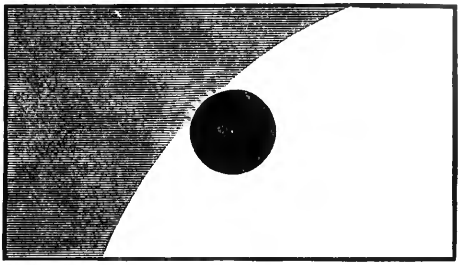


FIG. 4.

idea though on an exaggerated scale. The planet moves so slowly as to occupy more than twenty minutes in crossing the sun's limb; so that, even if the planet's edge were perfectly sharp and definite, and the sun's limb undistorted, it would be very difficult to determine the precise second at which contact occurs; but as things are, observers, with precisely similar telescopes, and side by side, often differ from each other five or six seconds; and where the telescopes are not similar the differences and uncertainties are much greater. The contact observations of the last transit in 1874 do not appear to be much more accordant than those of 1769, notwithstanding the great improvement in telescopes; and astronomers at present are pretty much agreed that such observations can be of little value in removing the remaining uncertainty of the solar parallax, and are disposed to put more reliance upon the micrometric and photographic methods, which are free from these peculiar difficulties, though of course beset with others; which, however, it is hoped will prove less formidable.

The micrometric method requires the use of a peculiar instrument known as the heliometer, an instrument common only in Germany, and requiring much skill and practice in its use in order to obtain with it accurate measures. At the late transit a single English party, two or three of the Russian parties, and all five of the German, were equipped with these instruments, and at some of the stations extensive series of measures were made. None of the results, however, have appeared as yet, so that it is impossible to say how greatly, if at all, this method will have the advantage in precision over the contact observations.

The Americans and French placed their main reliance upon the photographic method, while the English and Germans also provided

for its use to a certain extent. The great advantage of this method is that it makes it possible to perform the necessary measurements, upon whose accuracy everything depends, at leisure after the transit, without hurry, and with all possible precautions. The field-work consists merely in obtaining as many and as good pictures as possible. The only objection to the method lies in the difficulty of obtaining good pictures, i. e., pictures free from distortion, and so distinct and sharp as to bear high magnifying power in the microscopic apparatus used for their measurement. It is necessary also that the exact scale of the pictures, or the number of seconds of arc to the linear inch, be known, as well as the precise Greenwich time at which each picture is taken, and it is also extremely desirable that the *orientation* of the picture should be accurately determined, that is, the north and south, east and west points of the solar image on the finished plate. There has been a good deal of anxiety lest the image, however accurate and sharp when first produced, should alter in course of time through the contraction of the collodion film on the glass plate, but the experiments of Rutherfurd, Huggins, and Paschen, seem to show that this danger is imaginary; that if a plate is properly prepared the collodion film never creeps at all, but remains firmly attached to the glass. It requires but a very trifling amount of distortion or inaccuracy of the image to render it useless. The uncertainty in our present knowledge of the sun's parallax is so small that it would only involve an error of about one-quarter of a second in the calculated position of Venus on the sun's disk as seen from any station at any given time during the transit, and this would be about $\frac{1}{2000}$ of an inch on a four-inch picture of the sun. Unless, then, the picture is so distinct and free from distortion that the relative positions of Venus and the sun's centre can be determined from it within $\frac{1}{20000}$ of an inch, it is worthless as a means of correcting the received determination of the parallax.

But it is to be noted that any mere enlargement or diminution of the diameter of sun or planet will do no harm, provided it is alike all around the circumference of the disk, since the measurement is not from the edge of Venus to the edge of the sun, but between their *centres*. Photographic determinations of *contact*, on the contrary (such as Janssen and some of the English parties attempted by a peculiar and complicated apparatus), are affected with all the uncertainties of the old-fashioned observations of the eye alone, and with others in addition; so that, astronomically considered, they are entirely worthless, although interesting from a chemical and physical point of view.

Two essentially different lines of proceeding were adopted, at the last transit, in the photographic observations. The English and Germans attached a camera to the eye-end of an ordinary telescope, which was pointed directly at the sun; the image formed at the focus of the telescope was enlarged to the proper size by a combination of lenses

in the camera; and a small plate of glass ruled with squares was placed at the focus of the telescope and photographed with the sun's image, furnishing a set of reference-lines, which give the means of detecting and allowing for any distortion caused by the enlarging lenses.

The Americans and French, on the other hand, preferred to make the picture of full size, without the intervention of any enlarging lens: as this requires an object-glass with a focal length of thirty or forty feet, which could not be easily pointed at the sun, a plan proposed first, I believe, by M. Laussedat, but also independently by our own Prof. Winlock, was adopted. The telescope is placed horizontal, and the rays are reflected into the object-glass by a plane mirror suitably mounted. The French used mirrors of silvered glass, and took their pictures (about two and a half inches in diameter) by the old daguerreotype process on silvered plates of copper, in order to avoid the risk of collodion-contraction. With the silvered mirror the time of exposure is so short that no clock-work is required. The Americans used *unsilvered* mirrors, in order to avoid any distorting action of the sun's rays upon the form of the mirror. This, of course, made the light feebler, and the time of exposure longer, so that a clock-work movement of the mirror was needed to keep the image from changing its place on the plate during the exposure, which, however, never exceeded half a second. The American pictures were taken by the ordinary wet process on glass, and were about four inches in diameter. Just in front of the sensitive plate, at a distance of about one-eighth of an inch, was placed a reticle, or a plate of glass ruled in squares, and between this and the collodion-plate hung a fine silver wire suspending a plumb-bob. Thus the finished negative was marked into squares, and also bore the image of the plumb-line, which, of course, indicated precisely the direction of the vertical. The Americans also placed the photographic telescope exactly in line with a meridian instrument, and so determined, with the extremest precision, the direction in which it was pointed. Knowing this, and the time at which any picture was taken, it becomes possible, with the help of the plumb-line image, to determine precisely the orientation of the picture —an advantage possessed by the American pictures alone, and making their value nearly twice as great as otherwise it would have been.

The following figure is a representation of one of the American photographs reduced about one-half. V is the image of Venus, which on the actual plate is about one-seventh of an inch in diameter; $a\,a'$ is the image of the plumb-line. The centre of the reticle is marked by the little cross, and the word "China," written on the reticle-plate with a diamond—and, of course, copied on the photograph—indicates that it is one of the Peking pictures. Its number in the series is given in the right-hand upper corner. About 90 such pictures were obtained at Peking during the transit, and about 350 at all the eight American stations, the work being much interfered with by unfavorable weather

at most of them. If we add those obtained by the French, Germans, and English, the total number available reaches nearly 1,200, according to the best estimates.

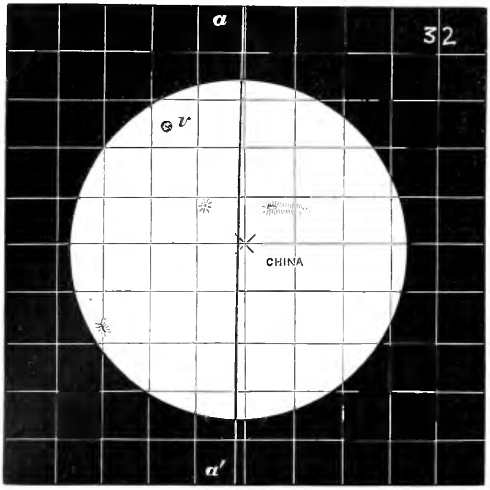


FIG. 5.

After the pictures are made and safely brought home, they have next to be measured—i. e., the distance (and in the American pictures the *direction* also) between the centre of Venus and the centre of the sun must be determined in each picture. This is an exceedingly delicate and tedious operation, rendered more difficult by the fact that the image of the sun is never truly circular; but, even supposing the instrument to be perfect in all its adjustments, is somewhat distorted by the effect of atmospheric refraction; so that the true position of the sun's centre with reference to the squares of the reticle is determined only by an intricate calculation from measurements made with a microscopic apparatus on a great number of points suitably chosen on the circumference of the image. The final result of the measurement would come out something in this form: Peking, No. 32, time, $14^h\ 08'\ 20.2''$ (Greenwich mean time); Venus north of sun's centre, 735.32″; east of centre, 441.63″; distance from centre of sun, 857.75″. (The numbers given are only imaginary.) It is this process of measurement which has required so long a time since the transit, and is not yet completed. When it is finished, and the results published in the form indicated, then will come the work of combining all the data thus obtained at all the stations, and from them deducing the true value of the solar parallax. Since, however, another transit is to occur so soon (in 1882), it is not unlikely that astronomers may defer the final grand combination until the observations of that transit also are ready to be included. It is very confidently hoped by most of those who have studied the subject that the remaining uncertainty in the

sun's distance will be greatly reduced as the result of this work; and yet there are some grounds for anxiety lest the photographic data prove as intractable and inconsistent as those derived from contact-observations. Time only can positively settle the question.

One of the best methods of determining the solar parallax is based upon the careful observation of the motions of the moon. It will be recollected that the first suspicion as to the correctness of the then received distance of the sun was raised in 1854 by Hansen's announcement that the moon's parallactic inequality led to a smaller value than that deduced from the transit of Venus—a conclusion corroborated by Leverrier four years later. It seems at first sight strange, but it is true, as Laplace long since pointed out, that the skillful astronomer, by merely watching the movements of our satellite, and without leaving his observatory, can obtain the solution of problems which, attacked by other methods, require tedious and expensive expeditions to remote corners of the earth. Our scope and object do not require us to enter into detail respecting this lunar method of finding the sun's parallax; it must suffice to say that the disturbing action of the sun makes the interval from new moon to full a little longer than that from full to new; and this difference depends upon the *ratio between the diameter of the moon's orbit and the distance of the sun* in such a manner that, if the inequality is accurately observed, the ratio can be calculated. Since we know the distance of the moon, this will give that of the sun. The results obtained in this way, according to the most recent investigations, fix the solar parallax between 8.83″ and 8.92″.

There is still another lunar method, mentioned in the synopsis; but its results are much less reliable—subject, that is, to a much larger probable error, though not at all contradictory to those just given.

But the method by which ultimately we shall obtain the most accurate determination of the dimensions of our system is that proposed by Leverrier, making use of the secular perturbations produced by the earth upon her neighboring planets, especially in causing the motions of their nodes and perihelia. These motions are very slow, but *continuous;* and hence, as time goes on, they will become known with ever-increasing accuracy. If they were known with absolute *precision, they would enable us to compute, with absolute precision also, the ratio between the masses of the sun and earth*, and from this ratio we can calculate[1] the distance of the sun by either of two or three different methods.

[1] One method of proceeding is as follows: Let M be the mass of the sun, and m that of the earth; let R be the distance of the sun from the earth, and r that of the moon; finally, let T be the number of days in a sidereal year, and t the number in a sidereal month. Then, by elementary astronomy,

$$M : m = \frac{R^3}{T^2} : \frac{r^3}{t^2}; \text{ whence } R^3 = r^3 \left(\frac{T^2}{t^2}\right) \left(\frac{M}{m}\right);$$

or, in words, *the cube of the sun's distance equals the cube of the moon's distance, multiplied*

As matters stand at present, the majority of astronomers would probably consider that these secular perturbations are not yet known with an exactness sufficient to render this method superior to the others that have been named—perhaps as yet not even their rival. Leverrier, on the other hand, himself puts such confidence in it that he declined to sanction or coöperate in the operations for observing the recent transit of Venus, considering all labor and expense in that direction as merely so much waste.

But, however the case may be now, there is no question that as time goes on, and our knowledge of the planetary motions becomes more minutely precise, this method will become continually and cumulatively more exact, until finally, and not many centuries hence, it will supersede all the others that have been described. The parallax of the sun, determined by Leverrier in this method, in 1872, comes out 8.86″.

The last of the methods mentioned in the synopsis given on page 405 is interesting as an example of the manner in which the sciences are mutually connected and dependent. Before the experiments of Fizeau in 1849, and of Foucault a few years later, our knowledge of the velocity of light depended on our knowledge of the dimensions of the earth's orbit: it had been found by astronomical observations upon the eclipses of Jupiter's satellites that light occupied a little more than 16 minutes in crossing the orbit of the earth, or about 8 minutes in coming from the sun; and hence, supposing the sun's distance to be 95,600,000 miles, as was long believed, the velocity of light must be about 192,000 miles per second; thus optics was indebted to astronomy for this fundamental element. But when Foucault in 1862 announced that, according to his unquestionably accurate experiments, the velocity of light could not be much more than 186,000 miles per second, the obligation was returned, and the suspicions as to the received value of the sun's parallax, which had been raised by the lunar researches of Hansen and Leverrier, were changed into certainty. The most recent experimental determinations of the velocity of light by Cornu in 1873–'74 fix the solar parallax between 8.80″ and 8.85″, according as we use Peters's "constant of aberration" or Delambre's value of the "equation of light," which is the name given to the time required for light to traverse the interval between the sun and the earth.

Collecting all the evidence at present attainable, it would seem that the solar parallax cannot differ much from 8.86″, though it may be as much as 0.04″ greater or smaller; this would correspond, as has

by the square of the number of sidereal months in a year, and by the ratio between the masses of the sun and earth. It is to be noted, however, that T and t are the periods of the earth and moon, as they would be if wholly undisturbed in their motions, and hence differ slightly from the periods actually observed—the differences are small, but somewhat troublesome to calculate with precision.

already been said, to a distance of 92,250,000 miles, with a probable error of about one-half per cent., or 450,000 miles.

But, though the distance can thus easily be stated in figures, it is not so easy to give any real idea of a space so enormous; it is quite beyond our power of conception. If one were to try to walk such a distance, supposing even that he could walk 4 miles an hour, and keep it up for 10 hours every day, it would take $68\frac{1}{2}$ years to make a single million of miles, and more than 6,300 years to traverse the whole.

If some celestial railway could be imagined, the journey to the sun, even if our trains ran 60 miles an hour, day and night and without a stop, would require over 175 years. Sensation, even, would not travel so far in a human lifetime. To borrow the curious illustration of Prof. Mendenhall, if we could imagine an infant with an arm long enough to enable him to touch the sun and burn himself, he would die of old age before the pain could reach him, since, according to the experiments of Helmholtz and others, a nervous shock is communicated only at the rate of about 100 feet per second, or 1,637 miles a day, and would need more than 150 years to make the journey. Sound would do it in about 14 years if it could be transmitted through celestial space, and a cannon-ball in about 9, if it were to move uniformly with the same speed as when it left the muzzle of the gun. If the earth could be suddenly stopped in her orbit, and allowed to fall unobstructed toward the sun under the accelerating influence of his attraction, she would reach the central fire in about four months. I have said if she could be stopped, but such is the compass of her orbit that, to make its circuit in a year, she has to move nearly 19 miles a second, or more than fifty times faster than the swiftest rifle-ball; and in moving 20 miles her path deviates from perfect straightness by less than one-eighth of an inch. And yet, over all the circumference of this tremendous orbit, the sun exercises his dominion, and every pulsation of his surface receives its response from the subject earth.

By observing the slight changes in the sun's apparent diameter, we find that its distance varies somewhat at different times of the year, about 3,000,000 miles in all; and minute investigation shows that the earth's orbit is almost an exact ellipse, whose nearest point to the sun, or *perihelion*, is passed by the earth about the 1st of January, at which time she is 90,750,000 miles distant.

The distance of the sun being once known, its dimensions are easily ascertained—at least, within certain narrow limits of accuracy. The angular semi-diameter of the sun when at the mean distance is almost exactly 962″, the uncertainty not exceeding $\frac{1}{2000}$ of the whole. The result of twelve years' observations at Greenwich (1836 to 1847) gives 961.82″, and other determinations oscillate around the value first mentioned, which is that adopted in the "American Nautical Al-

manac." Taking the distance as 92,250,000 miles, this makes the sun's diameter 860,500; and the probable error of this quantity, depending as it does *both* on the error of the measured diameter and of the distance, is some 4,000 or 5,000 miles; in other words, the chances are strong that the actual diameter is between 855,000 and 865,000 miles.

Measurements made by the same person, however, and with the same instrument, but at different times, sometimes differ enough to raise a suspicion that the diameter is slightly variable, which would be nothing surprising considering the nature of the solar surface. There is no sensible difference between the equatorial and polar diameters, the rotation of the sun on its axis not being sufficiently rapid to make the polar compression (which must, of course, necessarily result from the rotation) marked enough to be perceived by our present means of observation.

It is not easy to obtain any real conception of the vastness of this enormous sphere. Its diameter is 108.7 times that of the earth, and its circumference proportional, so that the traveler who could make the circuit of the world in 80 days would need nearly 24 years for his journey around the sun. Since the surfaces of spheres vary as the squares, and bulks as the cubes, of their diameters, it follows that the sun's surface is nearly 12,000 times, and its volume, or bulk, more than 1,280,000 times, greater than that of the earth. If the earth be represented by one of the little three-inch globes common in school apparatus, the sun on the same scale will be more than 27 feet in diameter, and its distance nearly 3,000 feet. Imagine the sun to be hollowed out and the earth placed in the centre of the shell thus formed, it would be like a sky to us, and the moon would have scope for all her motions far within the inclosing surface; indeed, since she is only 240,000 miles away, while the sun's radius is more than 430,000, there would be room for a second satellite 190,000 miles beyond her.

The *mass* of the sun, or quantity of matter contained in it, can also be computed when we know its distance, and comes out 325,600 times as great as the earth. The calculation may be made either by means of the proportion given in the note to page 413, or by comparing the attracting force of the sun upon the earth, as indicated by the curvature of her orbit (about 0.119 inch per second), with the distance a body at the surface of the earth falls in the same time under the action of gravity, a quantity which has been determined with great accuracy by experiments with the pendulum. Of course, the fact that the sun produces its effect upon the earth at a distance of 92,250,000 miles, while a falling body at the level of the sea is only about 4,000 miles from the centre of the attraction which produces its motion, must also enter into the reckoning.[1]

[1] The calculation of the sun's mass, from the data given, proceeds as follows: Let $M =$ the sun's mass, and m that of the earth; $R =$ the distance from the earth to the sun,

This mass, if we express it in pounds or tons, is too enormous to be conceived: it is 2 octillions of tons—that is, 2 with 27 ciphers annexed; it is nearly 750 times as great as the combined masses of all the planets and satellites of the solar system—and Jupiter alone is more than 300 times as massive as the earth. The sun's attractive power is such that it dominates all surrounding space, even to the fixed stars, so that a body at the distance of our nearest stellar neighbor, *a* Centauri, which is more than 200,000 times remoter than the sun, could free itself from the solar attraction only by darting away with a velocity of more than 300 feet per second, or over 200 miles an hour; unless animated by a greater velocity than this, it would move around the sun in a closed orbit—an ellipse of some shape, or a circle, with a period of revolution which, in the smallest possible orbit, would be about 31,600,000 years, and if the orbit were circular, would be nearly 90,000,000. We say it would revolve thus—that is, of course, unless intercepted or diverted from its course by the influence of some other sun, as it probably would be. And we may notice here that in many cases certainly, and in most cases probably, the stars are flying through space at a far swifter rate, with velocities of many miles per second.

If we calculate the force of gravity at the sun's surface, which is easily done by dividing its mass, 325,600, by the square of $108\frac{3}{4}$ (the number of times the sun's diameter exceeds the earth's), we find it to be $27\frac{1}{2}$ times as great as on the earth; a man who on the earth would weigh 150 pounds, would there weigh nearly two tons; and, even if the footing were good, would be unable to stir. A body which at the earth falls a little more than 16 feet in a second would there fall 443. A pendulum which here swings once a second would there oscillate more than five times as rapidly, like the balance-wheel of a watch—quivering rather than swinging.

Since the sun's volume is 1,280,000 times that of the earth, while its mass is only 325,600 times as great, it follows at once that the sun's *average density* (found by dividing the mass by the volume) *is only about one-quarter that of the earth.* This is a fact of the utmost importance in its bearing upon the constitution of this body. As we shall see hereafter, we know that certain heavy metals, with which we are familiar on the earth, enter largely into the composition of the

and r the mean radius of the earth; T, the length of the sidereal year, reduced to seconds; and $\frac{1}{2}$ g the distance a body falls in a second at the earth's surface. Now, the distance the earth falls toward the sun in a second, or the curvature of her orbit in a second, is equal to $\frac{2\pi^2R}{T^2}$ (about 0.119 inch). Hence, by the law of gravitation, $\frac{1}{2}g : \frac{2\pi^2R}{T^2} = \frac{m}{r^2} : \frac{M}{R^2}$, whence, $M = m\left(\frac{4\pi^2R^3}{T^2r^2g}\right)$.

In this formula make $\pi = 3.14159$; R, 92,250,000 miles; $T = 31,558,149.3$ seconds; $r = 3,956.179$ miles; and $g = 0.0061035$ mile (16.113 feet), and we shall get the result given in the text, viz., $M = 325,600$ m.

sun, so that, if the principal portion of the solar mass were either solid or liquid, its mean density ought to be at least as great as the earth's, especially since the enormous force of solar gravity would tend most powerfully to compress the materials. The low density can only be accounted for on the supposition, which seems fairly to accord also with all other facts, that the sun is mainly a ball of gas, or vapor, powerfully condensed, of course, in the central portion by the superincumbent weight, but prevented from liquefaction by an exceedly high temperature. And, on the other hand, it could be safely predicted on physical principles that so huge a ball of fiery vapor, exposed to the cold of space, would present precisely such phenomena as we find by observation of the solar surface and surroundings.

EDUCATION AS A SCIENCE.

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I.

THE scientific treatment of any art consists partly in applying the principles furnished by the several sciences involved—as chemical laws to agriculture—and partly in enforcing, throughout the discussion, the utmost precision and rigor in the statement, deduction and proof of the various maxims or rules that make up the art.

Both fecundity in the thoughts and clearness in the directions should attest the worth of the scientific method.

Definitions of the Scope of Education.—First, let me quote the definition embodied in the ideal of the founders of the Prussian National System. It is given shortly as "the harmonious and equable evolution of the human powers;" at more length, in the words of Stein, "by a method based on the nature of the mind, every power of the soul to be unfolded, every crude principle of life stirred up and nourished, all one-sided culture avoided, and the impulses on which the strength and worth of men rest carefully attended to."—(Donaldson's "Lectures on Education," p. 38.) This definition, which is pointed against narrowness generally, may have had special reference to the many omissions in the schooling of the foregone times: the leaving out of such things as bodily or muscular training; training in the senses or observation; training in art or refinement. It further insinuates that hitherto the professed teacher may not have done much even for the intellect, for the higher moral training, nor for the training with a view to happiness or enjoyment.

Acting on this ideal, not only would the educator put more press-

ure altogether on the susceptibilities of his pupils: he would also avoid overdoing any one branch; he would consider *proportion* in the things to be taught. To be all language, all observation, all abstract science, all fine art, all bodily expertness, all lofty sentiment, all theology—would not be accepted as a proper outcome of any trainer's work.

The Prussian definition, good so far, does not readily accommodate itself to such circumstances as these—namely, the superior aptitude of individuals for some things rather than for others; the advantage to society of preëminent fitness for special functions, although gained by a one-sided development; the difficulty of reconciling the "whole man" with himself; the limited means of the educator, which imposes the necessity of selection according to relative importance.

Although by no means easy, it is yet possible to make allowance for these various considerations, under the theory of harmonious development; but, after the operation is accomplished, the doubt will arise whether much is gained by using that theory as the defining fact of education.

In the very remarkable article on education contributed by James Mill to the "Encyclopædia Britannica," the end of education is stated to be "to render the individual, as much as possible, an instrument of happiness, first to himself, and next to other beings." This, however, should be given as an amended answer to the first question of the Westminster Catechism—"What is the chief end of man?" The utmost that we could expect of the educator, who is not everybody, is to contribute his part to the promotion of human happiness in the order stated. No doubt the definition goes more completely to the root of the matter than the German formula. It does not trouble itself with the harmony, the many-sidedness, the wholeness, of the individual development; it would admit these just as might be requisite for securing the final end.

James Mill is not singular in his over-grasping view of the subject. The most usual subdivision of education is into physical, intellectual, moral, religious, technical. Now, when we inquire into the meaning of physical education, we find it to mean the rearing of a healthy human being, by all the arts and devices of nursing, feeding, clothing, and general regimen. Mill includes this subject in his article, and Mr. Herbert Spencer devotes a very interesting chapter to it in his work on Education. It seems to me, however, that this department may be kept quite separate, important though it be. It does not at all depend upon the principles and considerations that the educator, properly so called, has in view in the carrying out of his work. The discussion of the subject does not in any way help us in educational matters, as most commonly understood; nor does it derive any illumination from being placed side by side with the arts of the recognized teacher. The fact of bodily health or vigor is a leading postu-

late in bodily or mental training, but the trainer does not take upon himself to lay down the rules of hygiene.

The inadvertence, for so I regard it, of coupling the art of health with education is easily disposed of, and does not land us in any arduous controversies. Very different is another aspect of these definitions: that wherein the end of education is propounded as the promotion of human happiness, human virtue, human perfection. Probably the qualification will at once be conceded, that education is but one of the means, a single contributing agency, to the all-including end. Nevertheless, the openings for difference of opinion as to what constitutes happiness, virtue, or perfection, are very wide. Moreover, the discussion has its proper place in ethics and in theology, and, if brought into the field of education, should be received under protest.

Before entering upon the consideration of this difficulty, the greatest of all, I will advert to some of the other views of education that seem to err on the side of taking in too much. Here, I may quote from the younger Mill, who, like his father, and unlike the generality of theorists, starts *more scientifico* with a definition. Education, according to him, "includes whatever we do for ourselves, and whatever is done for us by others, for the express purpose of bringing us nearer to the perfection of our nature; in its largest acceptation, it comprehends even the indirect effects produced on character and on the human faculties by things of which the direct purposes are different; by laws, by forms of government, by the industrial arts, by modes of social life; nay, even by physical facts not dependent on the human will; by climate, soil, and local position." He admits, however, that this is a very wide view of the subject, and for his own immediate purpose advances a narrower view, namely: "the culture which each generation purposely gives to those who are to be its successors, in order to qualify them for at least keeping up, and, if possible, for raising, the improvement which has been attained."—("Inaugural Address at St. Andrews," p. 4.)

Besides involving the dispute as to what constitutes "perfection," the first and larger statement is, I think, too wide for the most comprehensive philosophy of education. The influences exerted on the human character by climate and geographical position, by arts, laws, government, and modes of social life, constitute a very interesting department of sociology, and have their place there and nowhere else. What we do for ourselves, and what others do for us, to bring us nearer to the perfection of our nature, may be education in the precise sense of the word, and it may not. I do not see the propriety of including under the subject the direct operation of rewards and punishments. No doubt we do something to educate ourselves, and society does something to educate us, in a sufficiently proper acceptation of the word; but the ordinary influence of society, in the dispensing of punishment and reward, is not the essential fact of education, as I

propose to regard it, although an adjunct to some of its legitimate functions.

Mill's narrower expression of the scope of the subject is not exactly erroneous; the moulding of each generation by the one preceding is not improperly described as an education. It is, however, grandiose rather than scientific. Nothing is to be got out of it. It does not give the lead to the subsequent exposition.

I find in the article "Education," in "Chambers's Encyclopædia," a definition to the following effect: "In the widest sense of the word a man is *educated*, either for good or for evil, by everything that he experiences from the cradle to the grave [say, rather, 'formed,' 'made,' 'influenced']. But, in the more limited and usual sense, the term education is confined to the efforts made, of set purpose, to train men in a particular way—the efforts of the grown-up part of the community to inform the intellect and mould the character of the young [rather too much stress on the fact of influence from without]; and more especially to the labors of professional educators or schoolmasters." The concluding clause is the nearest to the point—the arts and methods employed by the schoolmaster; for, although he is not alone in the work that he is expressly devoted to, yet he it is that typifies the process in its greatest singleness and purity. If by any investigations, inventions, or discussions, we can improve his art to the ideal pitch, we shall have done nearly all that can be required of a science and art of education.

I return to the greater difficulty—namely, the question, what is the end of all teaching; or, if the end be human happiness and perfection, what definite guidance does this furnish to the educator? I have already remarked that the inquiry is acknowledged to belong to other departments; and, if in these departments clear and unanimous answers have not been arrived at, the educationist is not bound to make good the deficiency.

For this emergency, there is one thing obvious, another less obvious; the two together exhausting the resources of the educator.

The obvious thing is to fix upon whatever matters people are agreed upon. Of such the number is considerable, and the instances important. They make the universal topics of the schools.

The less obvious thing is, with reference to matters not agreed upon, that the educator should set forth at what cost these doubtful acquisitions would have to be made; for the cost must be at least one element in the decision respecting them. Whoever knows most about education is best able to say how far its appliances can cope with such aims as softening the manners, securing self-renunciation, bringing about the balanced action of all the powers, training the whole man, etc.

We shall see that one part of the science of education consists in giving the ultimate analysis of all complex growths. It is on such

an analysis that the cost can be calculated; and, by means of this, we can best observe whether contradictory demands are made upon the educator.

What we have been drifting to, in our search for an aim, is the work of the school. This may want a little more paring and rounding to give it scientific form, but it is the thing most calculated to fix and steady our vision at the outset.

Now, in the success of the schoolmaster's work, the first and central fact is the plastic property of the mind itself. On this depends the acquisition not simply of knowledge but of everything that can be called an acquisition. The most patent display of the power consists in memory for knowledge imparted. In this view the leading inquiry in the art of education is how to strengthen memory. We are, therefore, led to take account of the several mental aptitudes that either directly or indirectly enter into the retentive function. In other words, we must draw upon the science of the human mind for whatever that science contains respecting the conditions of memory.

Although memory, acquisition, retentiveness, depends mainly upon one unique property of the intellect, which accordingly demands to be scrutinized with the utmost care, there are various other properties, intellectual and emotional, that aid in the general result, and to each of these regard must be had, in a science of education.

We have thus obtained the clew to one prime division of the subject—the purely psychological part. Of no less consequence is another department, at present without a name—an inquiry into the proper or natural order of the different subjects, grounded on their relative simplicity or complexity, and their mutual dependence. It is necessary to success in education that a subject should not be presented to the pupil until all the preparatory subjects have been mastered. This is obvious enough in certain cases: arithmetic is taken before algebra, geometry before trigonometry, inorganic chemistry before organic; but in many cases the proper order is obscured by circumstances, and is an affair of very delicate consideration. I may call this the analytic, or logical, department of the theory of education.

It is a part of scientific method to take strict account of leading terms, by a thorough and exhaustive inquiry into the meanings of all such. The settlement of many questions relating to education is embarrassed by the vagueness of the single term "discipline."

Further, it ought to be pointed out, as specially applicable to our present subject, that the best attainable knowledge on anything is due to a combination of general principles obtained from the sciences, with well-conducted observations and experiments made in actual practice. On every great question there should be a convergence of both lights. The technical expression for this is the union of the deductive and inductive methods. The deductions are to be obtained

apart, in their own way, and with all attainable precision. The inductions are the maxims of practice, purified, in the first instance, by wide comparison and by the requisite precautions.

I thus propose to remove from the science of education matters belonging to much wider departments of human conduct, and to concentrate the view upon what exclusively pertains to education—the means of building up the acquired powers of human beings. The communication of knowledge is the ready type of the process, but the training operation enters into parts of the mind not intellectual—the activities and the emotions; the same forces, however, being at work.

Education does not embrace the employment of all our intellectual functions. There is a different art for directing the faculties in productive labor, as in the professions, in the original investigations of the man of science, or the creations of the artist. The principles of the human mind are applicable to both departments, but, although the two come into occasional contact, they are so far distinct that there is an advantage in viewing them separately. In the practical treatise of Locke, entitled "The Conduct of the Understanding," acquisition, production, and invention, are handled promiscuously.

BEARINGS OF PHYSIOLOGY.--The science of physiology, coupled with the accumulated empirical observations of past ages, is the reference in finding out how to rear living beings to the full maturity of their physical powers. This, as we have said, is quite distinct from the process of education.

The art of education assumes a certain average physical health, and does not inquire into the means of keeping up or increasing that average. Its point of contact with physiology and hygiene is narrowed to the plastic or acquisitive function of the brain—the property of fixing or connecting the nervous connections that underlie memory, habit and acquired power.

But as physiology now stands, we soon come to the end of its applications to the husbanding of the plastic faculty. The inquiry must proceed upon our direct experience in the work of education, with an occasional check or caution from the established physiological laws. Still, it would be a forgetting of mercies to undervalue the results accruing to education from the physiological doctrine of the physical basis of memory.

On this subject, physiology teaches the general fact that memory reposes upon a nervous property or power, sustained, like every other physical power, by nutrition, and having its alternations of exercise and rest. It also informs us that, like every other function, the plasticity may be stunted by inaction, and impaired by over-exertion.

As far as pure physiology is concerned, I invite everybody to reflect on one circumstance in particular. The human body is a great aggregate of organs or interests — muscles, digestion, respiration, senses, brain. When fatigue overtakes it the organs generally suffer;

when renovation has set in, the organs generally are invigorated. This is the first and most obvious consequence. It has next to be qualified by the remark that human beings are unequally constituted as regards the various functions; some being strong in muscle, others in stomach, others in brain. In all such persons the general invigoration is unequally shown; the favored organs receive a share proportioned to their respective capitals: to him that hath shall be given. Still more pertinent is the further qualification, that the organ that happens to be most active at the time receives more than its share; to exercise the several organs unequally is to nourish them unequally.

To come to the point as regards our immediate object. To increase the plastic property of the mind you must nourish the brain. You naturally expect that this result will ensue when the body generally is nourished: and so it will, if there be no exorbitant demands on the part of other organs, giving them such a preference as to leave very little for the organ of the mind. If the digestion or the muscles are unduly drawn upon, the brain will not respond to the drafts made upon it. Obversely, if the brain is so constituted by nature, or so excited by stimulation, as to absorb the lion's share of the nutriment, the opposite results will appear; the mental functions will be exalted, and the other interests more or less impoverished. This is the situation for an abundant display of mental force.

But we must further distinguish the mental functions themselves; for these are very different and mutually exclusive. Great refinement in the subdivisions is not necessary for the illustration. The broadest contrast is the emotional and the intellectual—feeling as pleasure, pain, or excitement, and feeling as knowledge. These two in extreme manifestation are hostile to each other: under extreme emotional excitement the intellect suffers; under great intellectual exertion the emotions subside (with limitations unnecessary for our purpose).

But intellect in the largest sense is not identical with the retentive or plastic operation. The laws of this peculiar phase of our intelligence are best obtained by studying it as a purely mental fact. Yet there is a physiological way of looking at it that is strongly confirmative of our psychological observations. On the physical or physiological side, memory or acquisition is a series of new nervous growths, the establishment of a number of beaten tracks in certain lines of the cerebral substance. Now, the presumption is that, as regards the claim for nourishment, this is the most costly of all the processes of the intelligence. To exercise a power once acquired should be a far easier thing, much less expensive, than to build up a new acquirement. We may be in sufficiently good condition for the one, while wholly out of condition for the other. Indeed, success in acquirement, looking at it from the physiological probabilities, should be the work of rare, choice, and happy moments; times when cerebral vigor is both abundant and well-directed.

Bearings of Psychology.—The largest chapter in the science of education must be the following out of all the psychological laws that bear directly or indirectly upon the process of mental acquirement. Every branch of psychology will be found available; but more especially the psychology of the intellect. Of the three great functions of the intellect, in the ultimate analysis—discrimination, agreement, retentiveness—the last is the most completely identified with the education process; but the others enter in as constituents in a way peculiar to each. I will select for my present paper, Discrimination and Retentiveness; and will endeavor to extract, from the discussion of these great intellectual functions, everything that they appear to yield for the ends of the educator. Although I can impart no novelty to the general statement of these functions, it is possible to make some unhackneyed remarks on their educational consequences.

Discrimination.—Mind starts from discrimination. The consciousness of difference is the beginning of every intellectual exercise. To encounter a new impression is to be aware of change: if the heat of a room increases ten degrees, we are awakened to the circumstance by a change of feeling; if we have no change of feeling, no altered consciousness, the outward fact is lost upon us; we take no notice of it, we are said not to know it.

Our intelligence is, therefore, absolutely limited by our power of discrimination. The other functions of intellect, the retentive power, for example, are not called into play, until we have first discriminated a number of things. If we did not originally feel the difference between light and dark, black and white, red and yellow, there would be no visible scenes for us to remember: with the amplest endowment of retentiveness, the outer world could not enter into our recollection; the blank of sensation is a blank of memory.

Yet further. The minuteness or delicacy of the feeling of difference is the measure of the variety and multitude of our primary impressions, and therefore of our stirred-up recollections. He that hears only twelve discriminated notes on the musical scale has his remembrances of sounds bounded by these; he that feels a hundred sensible differences has his ideas or recollections of sounds multiplied in the same proportion. The retentive power works up to the height of the discriminative power; it can do no more. Things are not remembered if they have not first been discriminated.

We have by nature a certain power of discrimination in each department of our sensibility. We can from the outset discriminate, more or less delicately, sights, sounds, touches, smells, tastes; and, in each sense, some persons much more than others. This is the deepest foundation of disparity of intellectual character, as well as of variety in likings and pursuits. If, from the beginning, one man can interpolate five shades of discrimination of color where another can feel but

one transition, the careers of the two men are foreshadowed and will be widely apart.

To observe this native inequality is important in predestining the child to this or that line of special training. For the actual work of teaching, it is of more consequence to note the ways and means of quickening and increasing the discriminating aptitude. Bearing in mind the fact that until a difference is felt between two things intelligence has not yet made the first step, the teacher is bound to consider the circumstances or conditions favorable and unfavorable to the exercise.

1. It is not peculiar to discrimination, but is common to every mental function, to lay down, as a first condition, mental vigor, freshness, and wakefulness. In a low state of the mental forces, in languor, or drowsiness, differences cannot be felt. That the mind should be alive, awake, in full force and exercise, is necessary for every kind of mental work. The teacher needs to quicken the mental alertness by artificial means, when there is a dormancy of mere indolence. He has to waken the pupil from the state significantly named *indifference*, the state where differing impressions fail to be recognized as distinct.

2. The mind may be fresh and alive, but its energies may be taking the wrong direction. There is a well-known antithesis or opposition between the emotional and the intellectual activities, leading to a certain incompatibility of the two. Under emotional excitement, the intellectual energies are enfeebled in amount, and enslaved to the reigning emotion. It is in the quieter states of mind that discrimination, in common with other intellectual powers, works to advantage. I will afterward discuss more minutely the very delicate matter of the management of the various emotions in the work of teaching.

3. It must not be forgotten that intellectual exercises are in themselves essentially insipid, unattractive, indifferent. As exertion, they impart a certain small degree of the delight that always attends the healthy action of an exuberant faculty; but this supposes their later developments, and is not a marked peculiarity in the child's commencing career. The first circumstance that gives an interest to discrimination is pleasurable or painful stimulus. Something must hang on a difference before the mind is made energetically awake to it. A thoroughly disinterested difference is not an object of attention to any one.

The transitions from cold to hot, dark to light, strain to relief, hunger to repletion, silence to sound, are all more or less interesting, and all more or less impressive. But then they are vehement and sensational. It is necessary, in order to the furnishing of the intelligence, that smaller and less sensational transitions should be felt; the intellectual nature is characterized by requiring the least amount of emotional flash in order to impress a difference. A loud and furious

demonstration will certainly compel attention and end in the feeling of difference, but the cost is too great to be often repeated.

4. The great practical aid to the discovery and the retention of difference is immediate succession or, what comes to the same thing, close juxtaposition. A rapid transition makes evident a difference that would not be felt after an interval, still less if anything else were allowed to occupy the mind in the mean time. This fact is sufficiently obvious, and is turned to account in easy cases, but is far from thoroughly worked out by the teacher and the expositor. Any trifling diversion will suffice to blind us to its importance.

We compare two notes by sounding them in close succession; two shades of color by placing them side by side; two weights by holding them in the two hands, and attending to the two feelings by turns. These are the plain instances. The comparison of forms leads to complications, and we cease to attempt the same kind of comparison. For mere length we lay the two things alongside; so for an angle. For number, we can place two groups in contiguous rows—three by the side of four or five—and observe the surplus.

Mere size is an affair of simple juxtaposition. Form, irrespective of size, is less approachable. A triangle and a quadrangle are compared by counting the sides, and resolving the difference of form into the simpler element of difference of number. A right-angled, an acute-angled, an isosceles triangle, must be compared by the juxta position of angles. A circle and an oval are represented by the alternatives of curvature and diameters: in the one, the curvature uniform and the diameters equal; in the other, the curvature varying and the diameters unequal. The difference between a close and an open curve is palpable enough.

The geometrical forms are thus resolvable into very simple bases of comparison; and the teacher must analyze them in the manner now stated. For the irregular and capricious forms, the elementary conceptions are still the same—lineal size, number, angular size, curvature—but the mode of guiding the attention may be various. Sometimes there is a strong and overpowering similarity, with a small and unconspicuous difference; as in our ciphers (compare 3 and 5), and in the letters of our alphabet (C, G), and still more in the Hebrew alphabet. For such comparisons, the difference, such as it is, needs to be very clearly drawn or even exaggerated. Another method is to have models of the same size to lay over one another, so as to bring out the difference through the juxtaposition. By an express effort, the teacher calls on the learner to view, with single-minded attention, the differing circumstance, and afterward to reproduce it by his own hand. An express lesson consists in asking the pupil what are the ciphers, or the letters, that are nearly alike, and what are the points of difference.

The higher arts of comparison to impress difference are best illus-

trated when both differences and agreements have to be noted. They would have to be resumed after the discussion of the intellectual force of agreement or similarity. The chief stress of the present explanation lies in regarding discrimination as the necessary prelude of every intellectual impression, as the basis of our stored-up knowledge, or memory. Agreement is presupposed likewise; but there is not the same necessity, nor is it expedient, to follow out the workings of agreement, before considering the plastic power of the intellect.

THE PRODUCTION OF COGNAC BRANDY.

THERE is a small district in the south of France known as the Deux Charentes, which has a commercial centre called Cognac. From the grapes of this district there comes a wine, and from this wine there is distilled a celebrated liquor which is named after the place, and called *Cognac brandy*. This spirit, *eau de vie supérieure*, as the French call it, is liked by a great many people, and hated by a great many more, so that it may fairly be assumed as an object of general interest. A writer in the *Pall Mall Gazette* has been at the pains to collect a large amount of information concerning it, to which we are indebted for the substance of the following statements.

England consumes by far the greater part of the supply; English firms practically control the export trade; and English influence is so potent in Cognac, that the rural population of the department speak jocularly of the place as the "little English town on the river Charente."

The Cognac-brandy district begins at Angoulême, about three hundred miles south of Paris, and comprises from fifty to sixty square miles. It is divided into five parts, and is cut in two from east to west by the river Charente. The parts are, in the order of their importance as established by the quality of the brandy they produce, though in the inverse order as to size, as follows: the Grande Champagne; the Petite Champagne; the Borderies, a strip of land along the banks of the Charente opposite the Grande Champagne; the Fins Bois; and the Bon Bois. The country is undulating. The surface, dotted with towns and villages, and diversified by occasional tracts of woodland between bright-green pastures on either bank of the river, is divided into fields spotted with walnut-trees and vineyards, with red-roofed farm-houses, and traversed by broad roads lined with rows of tall elms and poplars. The soil is principally clayey and flinty rock, supported by a bed of chalk or limestone, and occasionally of marl, that in the Grande and Petit Champagnes being of the best quality.

Eau de vie is a French term equivalent to the English word spirits, and hence is applicable to alcohols derived from any source. But the *eau de vie de Cognac* is the spirits obtained by distillation of the fermented juice of a few varieties of grape, chief among which is *la folle blanche* as it is called. This is a white grape. The name, which means literally "*the white fool*," is probably due to the fact that the *folle blanche* produces only a very inferior wine, which commands but eight cents a gallon, while a common red wine brings sixteen.

In the Deux Charentes there are three kinds of vineyards, called "*vignes pleines*," "*vignes en allées*," and "*vignes à bœufs*." In each the vines are planted in rows, which in the first are five feet apart. Hand-labor is generally employed in the cultivation, though the plough is used to loosen the ground where the rows are wide enough apart. The *vignes en allées* consist of long, narrow strips of land planted with vines in rows, every fourth or fifth row or so having a slip of ground sown with grain or vegetables in between. In these vineyards, which are more common in the Grande Champagne, the vines as a rule are planted rather wide apart. The *vignes à bœufs* are so termed from the rows being wide enough apart (from five to six feet) to admit of oxen and a plough passing between. The vines, as a rule, are left without supports. The producers are mostly small farmers, who cultivate their own vineyards, with little if any help. When help is employed, the wages vary from two to three francs a day, according to whether meals are furnished or not. These peasant proprietors are a frugal, saving class, and are not uncommonly rich.

It is unpleasant to relate that a speedy and almost complete suspension of this important industry is threatened in the ravages of the *Phylloxera vastatrix*, a minute and (to the naked eye) invisible insect, that preys on the roots and leaves of the vine, to the unfailing destruction of the plant. Large rewards offered by the French Government have had the effect of calling forth a number of remedies, but none of them have proved efficacious. During the year just past the insect spread nearly all over the Deux Charentes and reduced the vintage, so that it nowhere amounted to more than one-half a crop, and in some places not more than a tenth, the average being about one-sixth. Many farmers, in despair, actually cleared their fields and sowed them in grain. In many places a large part of the vines have been killed and the influence of the scourge was to cause a general neglect of the vineyards.

The grapes are picked, for the most part, by women wearing high-crowned fluted caps, who use a hook-shaped knife to sever the stems. Each carries with her a small wooden box with sloping sides, into which the fruit is thrown. When these boxes become full they are emptied into the baskets of the men who carry the grapes to the cart at the edge of the vineyard. The carts have long bodies and very high wheels. and a huge tub, fixed between four upright stakes. The

carriers, bending beneath their heavy loads, mount a ladder to the top of the tub, and by a peculiar twist of the body empty their baskets of grapes into it. Within the tub is a lad, who treads upon the grapes to reduce their bulk, and, in a measure, press out their juice. The cart being loaded, is drawn off by a yoke of oxen to the neighboring press-house. The grapes are next emptied, through an opening in the wall, upon a sloping stone floor, where they are crushed by an ordinary grape-mill, which, however, forces out only a portion of their juice. Formerly the juice was trodden out by the feet of the laborers. It runs down the sloping floor into a covered trough at the lower end, by which it is led into a tank—whence it is emptied into the casks, and then left to ferment.

As already said, the mill does not express all the juice from the grapes, and so the "must" is shoveled through an opening in the wall into a large, shallow trough at the foot of the press. Then it is heaped up in the centre of the trough, into what is called the *motte*, a form like a millstone, and subjected to powerful pressure. The sides of the *motte* are now trimmed, the screw loosened, and the trimmings piled on the top, when the pressure is again applied. This process is repeated until the must has been subjected to four pressures. Each pressure lasts about two hours, except the last, which, being generally put on in the evening, continues all night. Next day the must is spread out in the trough, watered from a watering-pot, and raked about in the water for an hour. The water being drawn off, the must is again put under pressure, and the juice obtained is mixed with the water, and the whole put into a cask to ferment.

The must, or juice, obtained from the milling and four previous pressures is put in casks, vats, or cisterns, to ferment, and it is from it that the *eau de vie supérieure* is obtained. The yield of fermented liquor in good seasons is, in the Grand Champagne, about 900 gallons to the acre; in the Deux Charentes, as a whole, about 500 gallons; and in some parts of the Bon Bois as low as 200 gallons. And, although, as already stated, the vineyards are generally small, crops of 20,000 to 50,000 gallons from particular ones were formerly known.

It is to be observed that the method of fermenting the wine intended for the distillation of brandy differs a little from that pursued with the red wine of the district: the murk being allowed to remain in the juice in the last case, while it is not allowed to do so in the first.

The still comprises a reservoir, with a pump for supplying it from a large stone tank below, and the usual furnace and retort, with head and worm. The average capacity of the stills throughout the Grand Champagne is only about fifty-five gallons at a single operation. The wine to be distilled having been emptied into a square stone tank, already referred to, is pumped into the reservoir, whence, through a tap, it is conveyed into the retort, which is heated with coal, at first

to a high degree, and afterward to a lower. At the end of several minutes a few drops of white, translucent liquid issue from the pipe of the worm, increasing soon to a little streamlet, which falls into a small cask. This liquid contains about half its weight of water, and is called the *brouillis*. It continues to flow until it becomes gradually less alcoholic, when a momentary pause occurs in the operation. A tap at the bottom of the retort is opened and the boiled wine, a brownish liquid, is either put back into the reservoir or allowed to run away. The wine from the reservoir is then turned into the retort until the latter is about two-thirds full. The same process is repeated, day and night, until all the wine has been converted into *brouillis*, which, being rectified, is then ready for delivery to the Cognac-brandy shippers as *eau de vie*. The proportion of brandy yielded by the wine is not fixed, but variable with certain circumstances. In a vintage of good quality it is one gallon of brandy to six or eight of wine; but in unfavorable seasons it is not more than one to seven and a half or twelve. Newly-made wine furnishes more spirit than wine twelve months old; and wine fermented in large bulk more, in proportion, than that fermented in small casks.

Cognac brandy is at first a colorless liquid, but it gradually acquires a pale yellow or amber color from the cask in which it is kept for ageing. With its natural appearance, however, it never appears to the consumer; public taste having become vitiated to the extent of requiring a rich brown or brandy color, which is imparted by a mixture of caramel or burnt sugar. Occasionally, too, a little red sanders-wood is used for coloring. The constituents are alcohol and water and small quantities of volatile oil, acetic acid, acetic ether, œnanthic ether, tannin, etc., and, as it reaches the consumer, coloring matter. The quantity of alcohol varies from 48 to 55 per cent.; the latter being the standard strength, or "proof." It is generally imported into England at 1 to 3 over proof, but the strength is lessened by age, so that, when taken from bond for sale, it seldom exceeds 3 or 4 under proof. The quality of the brandy depends not, as may be generally supposed, on the quantity of alcohol it contains, so much as on the minor constituents, notably the œnanthic ether, from which it derives its distinguishing smell and flavor. This fact becomes apparent when it is reflected that, while brandy, as is well known, improves with age, it loses thereby a part of its alcoholic strength. The very finest brandies, in fact, average from 5 to 10 under proof, and never rise above 2 under proof. In this connection, one or two interesting facts may be noted. It has already been stated that the grape from which the finest Cognac brandy is obtained yields at best an inferior wine. Now, the best wine-making grapes contain a comparatively large proportion of sugar, which varies from 12 to 26 and 30 per cent., and it is the sugar that in fermentation is converted into alcohol. The *folle*

blanche, however, contains a relatively small quantity of sugar, or only about 7 to 8 per cent. Again, the riper the grape the more sugar it will contain, but experience has taught the vine-dressers of the Deux Charentes that, if their grapes are allowed to thoroughly ripen, the brandy produced is stronger, but proportionally inferior in quality. So that all the facts lend confirmation to the statement just made.

It was remarked, a little while ago, that the quality, or "bouquet," of the brandy--that is, its peculiar odor—was derived from œnanthic ether. This ether is obtained from the seed of the grape, and, according to Neubauer, is a combination of various substances, of which caprylic and caproic acid ethers are the most important part.

The strength at which Cognac brandy is sold in England to consumers is from 11 to 12 under proof, to which it is lowered by the addition of water, after, it is said, it has passed into the hands of wholesale and retail dealers. The standard recognized in the brandy-trade is 10 under proof, and it is never lowered beyond 12 under proof, except by special agreement. Below 17 under proof it is seizable by the English excise.

It is the opinion of those, who have investigated the matter, that very little, if any, adulteration is practised before the brandy is shipped from France. Heavy penalties, imposed by the tribunals on certain Charente farmers, who some years ago were detected in the practice of doubling the quantity of their brandy by sophistication, have operated to prevent other farmers from falling into like practices; and a still more powerful deterrent is that no farmer can adulterate his brandy without making it known to his neighbors. In France no wine or spirit can be moved about without an official permit, and a distiller in the Charente could not receive a cask without everybody knowing it; so that any one who procured a raw spirit would at once become a marked man, and excluded from doing business with shippers. It is said that the farmers now confine their attempts to cheat to overstating the age of the brandy they offer for sale.

Besides water, the adulteration is chiefly made with inferior spirit. In addition to the dishonesty, there is much injury to health and life involved in the practice. There is a kind of alcohol known as *amylic*, or fusel-oil, contained in the spirits obtained from every substance except the grape, but in particularly large quantities in the spirits of potatoes, beet-root, and Jerusalem artichoke, which, being inferior, are those chiefly used for adulteration. This fusel-oil is a deadly poison. Says Dr. G. O. Drewry, "The public would not drink such a poison at any price if they were once awakened to a sense of its terrible nature." It is never formed in the presence of tartaric acid, which, as is well known, abounds in grape-juice; hence, spirits distilled from the pure juice of the grape contain no fusel-oil whatever.

It remains, before closing this paper, to speak of the manner of

collecting the brandy into the shipping-houses in Cognac, and of the treatment it receives therein. It is bought up from the distillers by commission-merchants, or shippers, who have large storehouses, supplied with facilities for filtering, mixing, ageing, etc. The two largest houses in the trade are those of the celebrated English firms, Martel & Co. and Hennessy & Co.; next to these are Otard, Dupuy & Co., and Augier Frères, the oldest house in Cognac; and besides these are many smaller ones. The farmers generally sell their spirit while it is new, or immediately after distillation. In the second year it is classed "stale," and in the fourth "old." On its arrival at the magazine it is tested by a sampler, to see that it corresponds with the representations made for it. It is measured in large *dépotoirs*, about 265 gallons capacity, which have glass tubes on the outside to indicate the quantity of spirit within. This is said to give a fairer measurement than smaller vessels. The price depends on the strength. For the English market this is classed at 58° of Gay Lussac's scale, or about 1° above English proof. For the French market it is 60°, and for the American 61°. It may as well be stated in this connection that England takes nearly the whole supply—her portion in 1875 amounting to 4,500,000 gallons. A small part is consumed in France, and other small parts go direct to the north of Europe, South America, and the United States.

Sales of spirits are based on the French scale—or 60°. For each degree above that standard the shipper pays the producer 5 per cent. extra; while for each degree under he deducts 10 per cent. After measurement the spirit is placed in new oaken casks, of the proper seasoning, and its age, quality, and origin, are indicated thereon. The casks are stored in a series of chambers threaded with tramways for moving them about; and in a vast gallery, beneath, stand long rows of conical-shaped colossal white vats, each more than twelve feet high and nine feet in diameter at its base. These are for use in mixing. By mixing, the peculiarities of the different varieties of spirit are blended, and so the "brands" are multiplied. In this process the various kinds are emptied, first, into a copper-plated trough on the floor above the vats, and at the same time passed through a filter ot flannel; then it is drawn off into the vat below, passing in its course through a second filter of white blotting-paper, surrounded by flannel. In the vats it is stirred by paddles—in some houses worked by hand and in others by machinery. This completes the mixing, and the spirit is drawn off into casks or bottles and stored for shipment. A part of the alcohol, estimated at 7 to 10 per cent., is lost by evaporation in the first year of ageing, and a considerably smaller part in subsequent years. The visible effect of this evaporation is displayed in the carbonized appearance of the walls and roofs of the older stone houses—a sootiness which the stranger is sure to attribute to the smoke of the distilleries, of which, however, there are none in Cognac.

UPS AND DOWNS OF THE LONG ISLAND COAST.

By E. LEWIS, Jr.

"Daily it is forced home on the mind of the geologist that nothing, not even the wind that blows, is so unstable as the crust of this earth."—Darwin, in 1835.

OBSERVATIONS made around the shores of Long Island justify the conclusion that they have undergone important changes in time geologically recent. These changes appear to have arisen from a series of vertical movements, by which the coast has been alternately elevated and depressed.

In consequence of these movements the shore-line of the island has advanced and again receded, perhaps, in repeated instances: being at one time, upon the ocean-side, from fifty to seventy miles southward of where the waves now break; while at another period the highest hills of the island were largely if not wholly submerged. The persistence and extent of these movements are interesting and important questions in geology. We do not know at present how great the oscillations of the coast may have been, but enough is obvious, in the records they have left in the contour and structure of the island, to show that they have been much greater than is indicated on the adjacent mainland of Southern New England. We shall endeavor to follow these records, obscure and perplexing though they sometimes are, back to the period in which Long Island may be said to have had its origin—a period which witnessed the approach and presence of a great ice-sheet upon this coast.

It is not questioned, we believe, that Long Island is a terminal glacial moraine, and that the material of which it is composed is the *débris* of regions over which the ice moved in its progress toward the sea. Its underlying portions are beds of laminated sands and clays which have been referred to periods antecedent to the advent of the ice, and which constitute in one sense a part of the island. Its great mass, however, overlies these beds, and presents two general forms of structure. One is known as the "unmodified bowlder-drift," in which there are no stratified beds; the other is the "modified drift," or that in which the material has been distributed in layers chiefly by the action of waves. Much of the hill-region of the island presents the peculiar pell-mell structure of the one—the stratified gravels and sands of Southern Long Island are typical of the other. These differences in structure, and other facts to be mentioned, imply great changes in the relative level of land and sea upon the coast.

In considering these movements of oscillation it will be convenient to notice the latest first, and others in their order. A persistent invasion of the ocean upon the shores of the island has taken place

in recent time, in consequence of which its bluffs have been undermined by waves, and the lowlands submerged. Immense bowlders lie upon some portions of the shores, which indicate the sites of recent banks and headlands.

The wearing away of an exposed coast, like that of the east end of Long Island, suggests a subsidence, by which it is continually being brought under dominion of the waves. Did no such change occur, the abrasion would be retarded, or might finally cease, unless, indeed, the falling material be removed by a coastwise drift of the water. The tendency of wave-motion is to throw upon shore the waste of the cliffs, thus raising a breakwater on which the waves expend their force. But, where low grounds along the ocean-margin become permanently overflowed, the proof is conclusive that a change of relative level has taken place. There has been no abrasion by waves, but silently and imperceptibly the tides have advanced upon the uplands.

Around the shores of Long Island are large areas of recent forest, swamp, and meadow, with remains of their peculiar forms of vegetation in many cases undecayed, covered by water to depths of from one to sixteen or more feet. Some facts illustrating this were presented to the Natural History Section of the Long Island Historical Society, in May, 1868, a synopsis of which was published in the *American Naturalist* for August of that year. A few of these, with others of importance since discovered, are offered in this paper.

The movement under consideration is by no means a local one, but occurs along the Atlantic border from Labrador to the Capes of Delaware, and in a lesser degree to Florida. Prof. G. H. Cook, in his admirable "Report on the Geology of New Jersey," cites many instances along the coast of that State where swamps of cedar and other forms of vegetation are now submerged, or covered with salt meadow.

On the south side of Long Island are about 40,000 acres of salt marsh and meadow. Their vast stretches of level surface, fringed by the Great South Bay and the beach on the one side, and by uplands on the other, present a scene of rare and surpassing beauty. The meadow rests upon a floor of gravel and sand. It varies in thickness from a few inches at the uplands to eight or ten feet near the beach, and is filled with the roots of grasses throughout. It has been formed by growth and accumulation at the surface, for the meadow-grasses thrive only at or near high-tide level where rainfall and sunshine can reach them. The increase of the meadow in thickness has, therefore, just kept pace with the deepening of the water, or in other words, with the sinking of the coast.

Beneath the meadows remains of swamp and forest are found. These are fast rooted, and often six feet beneath the surface. At Islip a great number of stumps are found in the salt meadow of Wil-

liam Nicol, Esq., remains of a forest, portions of which are still flourishing on the adjacent uplands. These, Mr. Nicol writes, "are of oak, and are from twelve to twenty-four inches in diameter." Similar ones, he is informed, occur on the north side of the beach close to the ocean, which are covered by three feet of water at low tide. Eastward from this point the bay is broad and shallow for upward of twenty miles. The depth of water in it is from three to eight feet, with from two to three feet more in some parts of the channel. A tradition of the early settlers, which appears to have been received from the aborigines, is, that the whole area was once a fresh-water swamp, portions of which were so nearly dry at certain seasons of the year, that the Indians passed over it dry-footed to the beach.

A hundred and fifty years ago the bottom of this bay was covered in many places with remains of swamp vegetation, and stumps of trees, to the "great annoyance and astonishment of fishermen."

It is probable that this section of the bay was at one time a swamp or series of swamps like many now found on the contiguous uplands, and sufficiently above the level of the sea to admit of their free drainage into it, for it is certain that they were supplied by the same copious streams from the island which now empty into the bay.

The character of these swamps changed when the tides overflowed them. That the bay is comparatively modern is suggested by the fact that no great mounds of shells[1] occur near it, such as were left by the aborigines along other parts of the coast. Yet it is certain that the country was thickly settled by Indians. Mr. Nicol writes, "There are fields known as old Indian fields which abound in shells, but they nowhere take the form of mounds."

A few miles eastward is the beautiful but shallow sheet of water known as Tiana Bay. It fills a depression in the almost level sands along this part of the coast, and is upon the site of a pine-forest. W. S. Pelletreau, Esq., of Southampton, informed us that he saw in it about three hundred stumps covered at low tide. They are of the same species of pine which now grows on the adjacent uplands.[2]

In Peconic Bay, which divides the eastern part of Long Island into two very long necks of land, the submergence of the shores has been extensive. Mr. E. F. Squires, of Riverhead, noticed not only areas of swamp, but of former cedar-forests, now permanently overflowed by the tides. One point is known as "Stump Landing."

On the north shore of the island are several tracts of "sunken meadow," over which the water at low tide is from ten to fifteen feet

[1] Westward of this portion of the shore of the "Great South Bay" are many "Indian shell-heaps," all of them now surrounded by meadows. Some of them, six or more feet deep, near the margin of the ocean, are covered by every tide. These are probably very old, and were formed originally at the uplands.

[2] The pitch-pine (*Pinus rigida*). This tree almost rivals the maritime pine of Europe in flourishing at the verge of salt-water. Emerson states that it is not killed by occasional overflow of the tides.

deep. These dead and submerged meadows are but little decayed, and are usually continuous with those now growing upon the shores.

On the flat shores of the south side of the island the encroachment of meadow upon the uplands is attended with interesting results. It forms first in depressions where the tides overflow. In this way knolls of upland, cultivated or perhaps covered with trees, become islands, which are in turn overflowed and covered by meadow, but some of the more elevated ones remain almost at the verge of the ocean. Barnum's, formerly Hog Island, in East Rockaway Bay, now being converted into an asylum for the paupers of Queen's County, is one of these.

It is well known that the beach[1] on which the ocean breaks is gradually thrown inland upon the meadows. By this means old meadows are sometimes laid bare. It is stated, in Furman's "Antiquities of Long Island," that when Jones's Inlet was opened through the beach during a storm, it was found that the "bottom, laid bare, was solid meadow, in which were tracks of cattle, or of cloven-footed beasts."

The old meadow-bottoms, and sometimes masses of the tangled roots of upland vegetation, are torn up by waves during storms and thrown upon the beach. We have seen this turfy matter lying like windrows along the surf. Mr. Pelletreau informs us that just opposite the east end of Shinecock Bay "there was washed out by waves a large quantity of what is called meadow-bottom, partially decomposed vegetable matter, remains of fresh-water plants. . . . A few years since a violent storm washed away the sea-beach near Southampton, exposing at low tide, nearly at the brink of the ocean, a row of fence-posts that were put down by the first settlers." From these and other facts this careful observer concludes that the ocean, in that vicinity, has encroached upon the land about half a mile in two hundred years.

At Montauk Point, north of the lighthouse, is a low, swampy place, over which the tides sometimes rise. We are informed by Mr. J. F. Gould, who was for many years keeper of the lighthouse, that stumps are laid bare in front of this swamp, at the sea-margin, when the tide is extremely low. A similar phenomenon occurs at the extreme westerly end of the island. A few rods south of Fort Hamilton, at the entrance of New York Harbor, are the well-known Dyker Meadows (Fig. 1). They occupy the site of a swamp which is filled with the remains of upland and fresh-water vegetation.

The swamp was originally about a mile long, and was in one of the valley-shaped depressions common on the surface of the Long Island drift. It lost its character as a swamp by encroachment of the tides upon it, and was finally converted into a salt-marsh. This

[1] This breakwater of sand extends from Coney Island to the hills of Montauk, a distance of nearly one hundred miles.

marsh abounds in stumps; a great number of large size, some of them three feet in diameter, have been seen by the writer at the verge of low water, and we have found them many rods from the shore where the water was ten feet deep.[1] This area was certainly a portion of the original swamp when the land was sufficiently elevated to lift it above the level of the sea.

It is not necessary to further illustrate the present subsidence of this coast, but evidence of the extent of the movement will be of interest.

Fig. 1.—Section through the Dyker Meadows.
Horizontal scale, four inches to the mile; vertical scale, twenty feet to the inch.

In constructing the Erie Basin at Brooklyn in New York Harbor, Mr. George B. Brainerd, engineer, found the following series of deposits, the water being ten feet deep at low tide: Three and a half feet of mud, sand, etc.; ten feet compact peaty meadow. This gives twenty-three and a half feet of depression since the bottom of that meadow was the surface, and covered with vegetation at the level of the sea.

In 1867 John Nadir, Esq., United States Engineer at Fort Hamilton, carefully examined, by boring, the underlying formation around Fort Lafayette. The earth was penetrated to a depth of 53 feet at points between 800 and 1,000 feet from the shore, where the water at low tide was ten feet deep. The deposits passed through were as follows: twenty feet coarse sand and gravel, with few broken shells; three feet decayed meadow, with shells and *Diatomaceæ;* seventeen feet gravel and sand, with broken shells; thirteen feet mud, quite compact, which appears to have been a marsh with scanty vegetation, and shells.[2] This indicates a subsidence of the coast of at least sixty-three feet, or, in other words, the land of the coast was that number of feet higher than it now is, when the subsidence began. But there is reason to conclude that the elevation was much greater than sixty-three feet. If we take a step backward in the order of events, we find that, immediately previous to the elevation mentioned, there occurred a great depression of the coast. Possibly the highest hills of the

[1] "Cedar-swamps, buried beneath the meadows on the New Jersey coast, have yielded logs six feet in diameter, and some with 1,000 rings of growth."—*Prof. Cook's Report.*

[2] The shells were identified by Mr. A. R. Young, of Brooklyn, as follows: *Nassa obsoleta*, *Anomia ephippium*, *Mya arenaria*, *Crepidula fornicata*, *Solen ensis*, and *Mytilus edulis*.

island were carried under water. The evidences of this depression are found in the numerous beds of stratified sand and gravel—elevated beaches and other shore-formations—which lie along the central ridge of hills,[1] and fronting the ocean from 100 to 260 or more feet above the level of the sea. At whatever heights these deposits occur, they suggest, if they do not prove, submergence of the coast to that extent.

From observations, made by the writer and others, it is ascertained that the summit of Hempstead Harbor Hill, which is 384 feet above tide, and the highest land upon Long Island, is a mass of stratified sand and gravel. The same is true of Janes Hill, in the West Hill group, said to be 383 feet high, and of Osborn's Hill, southwest of Riverhead, the height of which, according the United States Coast Survey, is 293 feet. In these instances, and in others similar, the layers are distinct and well defined. The stratification of this material was evidently the work of waves, but, whether of the ocean, or of a glacial lake or sea, admits of doubt. At present we cannot determine what the extent, contour, or elevation of the surface around these dome-like hills may have been; nor can we tell the original extent of the beds of assorted material, remains of which now cap the hills. That the denudation has been immense, is everywhere evident.

From the summits of the hills mentioned one overlooks southward a vast plain which extends to the ocean, ten miles distant; and the conclusion seems irresistible that every rood of that distance has been the shore-line of first an invading, afterward of a receding ocean, and the scene of those great coast-changes which waves produce. We may restore, in imagination, the hills of glacial rubbish crumbling before the stroke of waves, as during an immense period of time the subsidence of the land went on. So complete was the work of disintegration, that scarcely a bowlder remains in the low tracts fronting the ocean, but are numerous along the margin of the hills, and abound in the undisturbed drift[2] which constitutes much of the hill-region.

The period of subsidence we are considering is referred to the "Champlain" of the geologists, so called by Prof. C. H. Hitchcock from the abundance of its peculiar deposits near that lake. It is a marked one in geological history. During its progress the deposits

[1] A ridge of hills, varying in height from one hundred and fifty to three hundred and eighty-four feet above tide, extends, with some interruptions, through Central Long Island. They are drift with bowlders; but nowhere show rock in place, as some have supposed.

[2] Many bowlders on Long Island are of immense size; one, at Manhassett, contains upward of 20,000 cubic feet. Two others now or recently in the same valley are, in circuit, 108 and 126 feet respectively. One, on Strong's Neck, in Suffolk county, has a content of 14,000 cubic feet. Bowlders are found on the tops of the highest hills, and form an enormous rip-raps in some places where they have fallen as the banks were undermined by waves.

which the glaciers had left were altered in their contour, and redistributed by waters which encroached upon and finally covered them. The material thus redistributed would be left in layers, chiefly of gravels, sands, and clayey sands, if upon the ocean-margin, as is the case in Long Island.

In sinking wells into the beds formed during this period of subsidence, wood and shells have been found in a great number of instances. The wood sometimes occurs in logs of large size; oak and pine have been identified. We have a record of sixteen instances where wood has recently been found, and many others are mentioned by Thompson in his history, and by Mather in his excellent report on the geology of the island. These facts seem to imply that forests were upon the adjacent lands, which was not the case during the presence of glaciers upon the coast.

The shells found are at various depths—in one case at Gravesend 100 feet below the surface—and occur in all parts of the island where the stratified drift abounds. They have been found at Flatbush, Prospect Park, Bath, East New York, Farmingdale, Amagansett, and elsewhere.

The beds in which they occur are not of the low plains only, but many feet above tide. At Manhassett, as we are informed by John M. Clark, Esq., of that place, a well was dug, and at several feet below the surface-rubbish a layer of what appeared to be "creek-mud" was found, in which were a great number of shells of the oyster, clam, and scallop, many of them unbroken. The layer was about five feet thick, and throughout contained not only shells, but leaves, pine-cones, also wood of pine and other species. This interesting deposit is about 200 feet above tide; but the contour of the present surface indicates plainly enough that an arm of a bay (Little Neck Bay) contiguous extended over this area when the land was sufficiently submerged to admit of it.

It is obvious that only the portion of Long Island which is more than 200 feet above tide was at that time dry land.

But the subsidence was greater than is indicated by this elevated deposit. The peculiar beds of stratified sands and gravels on the low plains already referred to, and which prove the former presence of the sea, are found at elevations of from 200 to 260 feet along the margins of the hills, and against or upon the unmodified bowlder-drift (Fig. 2). Beach-sands occur at 230 feet elevation, having the well-known structure of such beds. We have, too, the further fact, already noticed, that the tops of some of the highest hills of our island are composed of stratified gravel and sand.

Without insisting further on this fact, however, we think a movement of subsidence is shown thus far of at least 260 feet; but facts of a most interesting and important character now being brought to light show that this is but part of the great movement of depression

of the period we are considering. An artesian well is being bored on Barnum's Island, already mentioned, within two miles of the ocean. The island is but a knoll of tillable upland, surrounded by meadows and the waters of the bay.

The boring has reached a depth of 368 feet, or about 358 feet below

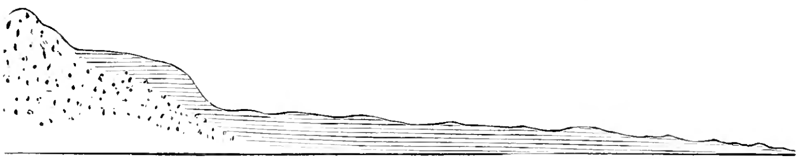


FIG. 2.—SECTION FROM HILLS AT CENTRE OF THE ISLAND, NEAR WHEATLY, TO THE OCEAN, SHOWING STRATIFIED BEDS OVERLYING THE UNMODIFIED DRIFT.
Vertical section, one inch to five hundred feet. Horizontal section, one inch to three miles.

tide-level, and is still in progress. We present below a statement of the series of deposits penetrated. Our table is prepared from the record of Theodore F. Carman, Esq., of Hempstead, Long Island, engineer of the work, and from eighty specimens of the layers passed through, furnished by that gentleman:

1.—70	feet.	Yellowish gravel and sand.
2.—56	"	Clay. Upper portions with decayed vegetation, wood, and lignite.
3.— 3	"	Coarse gravel and sand.
4.—46	"	Sands, with clayey crusts and pyrites.
5.—25	"	Sands, with some lignite.
6.—54	"	Clayey sands.
7.—94	"	Fine sand, sandy clay, with much lignite in the more clayey portions.
8.— 4	"	Fine sand.
9.— 1	"	Very firm bed of lignite, in fine decayed vegetable matter and clay.
10.—10	"	Clay, with lignite.
11.— 3	"	Clay, very fine, without lignite.
12.— 2	"	Sandy clay.
Total, 368		

Our grouping of the deposits may suggest transitions more sharp than the specimens warrant. About 70 feet of the surface is of yellow or orange colored sand and gravel. Then occurs a bed of clay 56 feet thick, on the surface of which was found decayed vegetable matter having a strong odor of carbolic acid. Wood and lignite occurred in this bed. Beneath was found a layer of coarse gravel and sand.

None of the layers penetrated are of the unmodified drift. No shells have been found, nor other remains of animal life, excepting a very small fragment of a crinoidal stem which occurred in a thick bed of coarse silicious sand 160 feet below the surface. This specimen, which is much water-worn, Prof. Dana suggests may be of cretaceous species, but it affords little or no evidence that the deposit in which it was found is of Cretaceous age. The Silurian and Devonian fossils, which occur frequently in the drift of Long Island, cannot be considered as proof that the deposits are Silurian or Devonian.

With the specimens before us, we think these surface-beds, to a depth of about 180 feet, are post-glacial, and are formed from glacial drift. Below this depth the beds are of dark clay and clayey silt-like sand, alternating with deposits of sand similar to that of the beaches upon the coast. Lignite occurs throughout, and a layer of it at 353 feet was penetrated with difficulty by the implements employed in boring the well.

The lignite found throws little light on the age of the beds. It is brought to the surface in small pieces, and that from the surface of the clay bed at 353 feet was formed from small stems of exogenous structure. The same is true of that found on the bed at 70 feet. This deposit of clay, 56 feet in thickness, seems closely analogous to many clays now upon, and at various depths beneath, the surface of the island. It is evidently a local deposit, such as might occur in a depression of the surface. Two tube-wells have been driven at no great distance from Barnum's Island, one 97, the other 194 feet, in which no similar layer of clay was detected. No green sand or marl deposits have been found. It seems probable that the beds below a depth of 180 feet were formed in tranquil waters of no great depth, possibly in an estuary sheltered by a beach of sand from the waves, into which streams discharged the waste of what was evidently a forested region. That they are preglacial, is, we think, quite certain. The period of transition between the Tertiary and the Drift, when the distant but advancing ice-sheet sent on its swollen streams, best answers the conditions. The existence of beds of stratified gravel and sand at 260 feet above the level of the ocean, and of similar beds at 180 feet below it, which we refer to the period of the Champlain subsidence, proves that a depression took place of at least 440 feet, and further that the coast was at least 180 feet higher than now when the depression began. That the elevation was much greater than that will be obvious as we proceed.

The glacial drift of Long Island, of which the Champlain deposits were formed, is without fossils, excepting such as occur in bowlders from older beds. But underneath it is a deep deposit of sands, gravels, and clayey sands, in which fossils have been found. Shells of the clam and oyster were taken from sands beneath the bowlder-drift at Lakeville, at a depth of 140 feet, by Henry Onderdonk, Jr., Esq., and a mass of shells, chiefly oyster, were found in sinking the well of the Nassau Gas-Light Company in Brooklyn, 127 feet below the surface, beneath a layer of unmodified drift, 70 feet thick. In this drift were many bowlders. A section of this well is shown in Fig. 3.

In digging wells these sandy and gravelly layers are generally found beneath the bowlder-drift; and the shells, wood, and lignite, evidently represent a period of milder climate than prevailed during the Ice period. Possibly they were deposited on the coast by the floods and swollen streams of the approaching glacier, and the coarse-

ness of the upper portions may suggest a shoaling of the coast from an upward movement of the land as the Ice period came on.

That an elevation occurred during the progress of the Ice period is evident from the contour, as well as structure, of the drift of Long Island. On the north side of the island are numerous fiord valleys, constituting a series of harbors of unsurpassed beauty. They extend

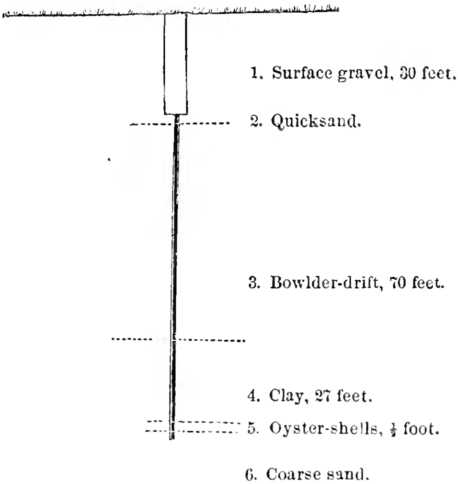


FIG. 3.—SECTION OF THE NASSAU GAS-LIGHT COMPANY'S WELL IN BROOKLYN.

into the island from two to six miles, having depths of water from ten to thirty, and in some instances fifty feet. Beneath the water is a deep deposit of ooze or sediment, known to be in one case forty feet thick. The banks on either side are from a few feet to 200 feet high.

It is apparent that these enormous valleys were not wholly cut into the drift after it was deposited, but rather were maintained while the deposit of drift was in progress, as valleys or water-courses, through which glacial streams may have been discharged into the ocean. These became filled, however, by an excessive accumulation of drift, as from rapid wasting of the ice, causing the outflowing streams to be arrested, and the waters to be discharged eastward or westward from Long Island Sound. But whether they were formed as we suggest, or were cut into the drift after it was deposited, it is quite certain that the coast was sufficiently elevated to permit the glacial floods to sweep the bottom of those valleys.

The 70 feet of drift of the Nassau Gas-Light Company's well is wholly below tide, and its unmodified structure shows that it was deposited above the sea-level, or out of the reach of waves, and further confirms the elevation of the coast in the glacial period.

But evidence of the elevation of the coast during the progress of

the Ice age is shown in the interesting fact revealed by the United States Coast Survey, and noticed by Prof. Dana, that the old valley of the Hudson River exists a well-defined depression in the bed of the ocean through a distance of 89 miles southeastward from Sandy Hook. It is termed on the Coast Survey chart "a remarkable gorge." The soundings show that it comprises a continuous series of deep depressions in the ocean's bottom. Some of these are eight miles long and from one and a half to two and a half miles wide. The map (Fig. 4), kindly furnished by the publishers of Prof. Dana's "Manual of Geology," shows how the dotted lines of equal depths bend toward Sandy Hook, indicating the line of deepest water, or the old river-valley in question.

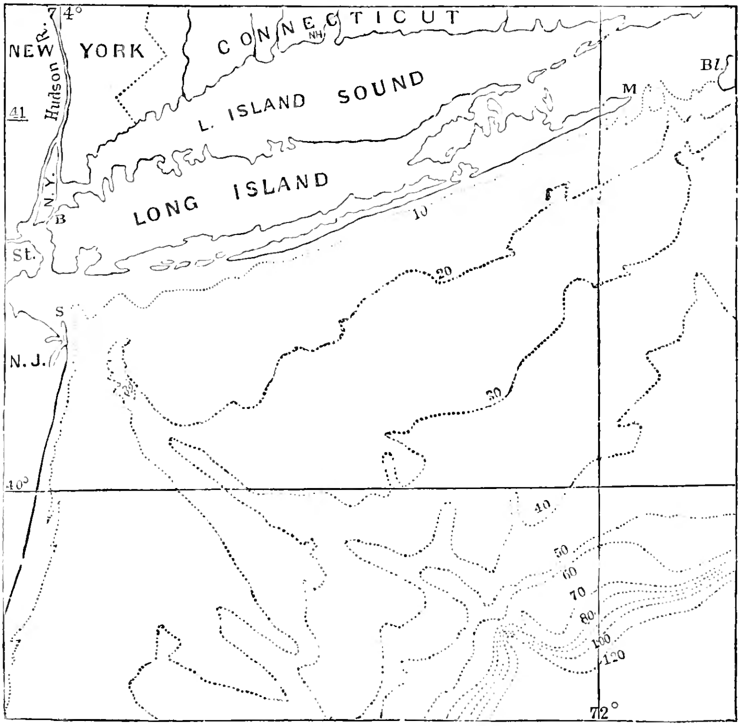


FIG. 4.—MAP OF THE SUBMERGED BORDER OF THE CONTINENT OFF LONG ISLAND AND NEW JERSEY, WITH LINES OF EQUAL SOUNDINGS IN FATHOMS. (From Dana's "Manual of Geology," p. 422.)

The Coast Survey chart shows us that at 28 miles from Sandy Hook the depression is 90 feet below the banks or ocean-bottom on either side. At 39 miles and at 51 miles the depression is 60 feet, and at 74 miles it is 72 feet, and at 89 miles it is 492 feet.

The average depth of the ocean over this depression is about one-third greater than on either side.

Through this valley, probably much deeper than now, during the period of elevation the Hudson flowed on its way to the ocean. Had it been, as it now is, deeply submerged, no river could have flowed in it, nor could it have been maintained as a valley while the deposit of drift was going on. The facts imply elevation of the region to an extent of from 300 to 400 feet above the present level of the sea. This would change in a marked manner the aspect of the coast. The site of the city of New York would be inland and greatly elevated, while the gorges of the Hudson and East Rivers would be deepened and widened by glacial torrents and ice. The ocean-border would be from 70 to 80 miles southward from the present shore of Long Island, and the deepest point attained in the artesian well on Barnum's Island would be above the level of the sea.

There is reason to conclude that the entire subsidence of our coast, from its greatest elevation in the glacial age to the greatest depression of the Champlain period which followed it, was from 600 to 700 feet, possibly much more than that. The elevation which followed carried its stratified deposits not only to their present height above tide, which, as we have seen, is about 260 feet, but at least 63 feet more than that when the buried marsh at Fort Lafayette was formed at the surface. By the present subsidence it is submerged or buried to that depth.

Here we pause. Further observations may confirm or correct our conclusions. Geology has not a more tangled skein than is presented in the structure of Long Island. There is evidence of minor oscillations, and pauses of movement, during which great clay deposits formed in depressions upon the surface, now deeply covered with drift or stratified sands, affording also some evidence that interglacial periods, perhaps of mild climate, occurred, but more observations and more facts are needed to justify a definite judgment on the subject.

Underneath the glacial drift, and underneath the sands which we refer to the advent of the ice, are beds of clay and colored sands which appear to be independent of the drift, and are referred to Tertiary or Cretaceous periods. They appear at the surface along the north side of the island, and are found buried by both unmodified drift and by coarse glacial rubble.

We present in tabular form the series of deposits which seem well defined on Long Island, and which represent the probable order of events, but they are fragmental, and perhaps do not occur anywhere in a continuous vertical series:

1. Shore and other surface formations.
2. Stratified gravels and sands of the Champlain subsidence—with fossil shells of clam, oyster, and scallop; also wood and lignite.
3. Coarse glacial rubble in deep beds without fossils, representing floods at the close of the Ice period, chiefly on the north side of the island.
4. Unmodified bowlder-drift without fossils.

5. Stratified gravels and sands with fossil shells of the oyster, also wood and lignite underneath the bowlder-drift.

6. Laminated sands and clays with decayed vegetation and lignite have been found; also one shark's tooth (*C. angustidens*).

7. The above beds seem to merge into more clayey sands, and in the deeper portions fine dark-colored plastic clay.

The period we have considered is one of immense duration, but throughout there is no evidence of sudden or violent changes. No catastrophe has "set Long Island off from the mainland." In its wonderfully complex structure it is a monument of a state of things which has passed away, but also of a series of movements of oscillation which has continued to the present time.

But it is only after long periods of time that these become obvious, and we realize how completely old landmarks have disappeared.

The tourist in Italy lingers with astonishment before the erect columns of the temple at Pozzuoli in the bay of Baiæ, and sees, at a height of twenty feet above their base, proof of their long submergence in the waters. Moore said of them:

"These lonely columns stand sublime,
Flinging their shadows from on high,
Like dials which the wizard Time
Has raised to count his ages by."

But, on our own shores, beneath the clear waters, and on the hills we cultivate, are records of similar movements, vastly greater in extent, and running with marvelous continuity through periods so vast that all the centuries which have passed since the Pozzuoli marbles were erected seem but as yesterday.

AN AMERICAN ASTRONOMICAL ACHIEVEMENT.

By RICHARD A. PROCTOR.

An American astronomer, Prof. Young, of Dartmouth College, Hanover, New Hampshire, has recently achieved a victory over a problem which has for many years foiled the skill of the best European observers; and, in so doing, he may be said to have added the keystone to an arch of no small importance in the edifice of modern astronomical science. It will be in the knowledge of most of my readers that astronomers have succeeded, during the last eight years, in measuring the rate at which some of the stars travel from or toward us, employing for the purpose what is called the spectroscopic method. I do not mean here spectroscopic analysis simply, but a special application of this now familiar analysis to measure the rate at which luminous bodies are approaching us or receding from us.

The principle of the method is very readily explained. Light comes to us from the heavenly bodies, as from other luminous bodies, in waves, which sweep through the ether of space at the rate of about 185,000 miles per second. The whole of that region over which astronomers have extended their survey, and doubtless a region many millions of millions of times more extended, may be compared to a wave-tossed sea, only that instead of a wave-tossed surface there is wave-tossed space. At every point, through every point, along every line, athwart every line, myriads of light-waves are at all times rushing with the inconceivable velocity just mentioned. It is from such waves that we have learned all we know about the universe outside our own earth. They bring to our shores news from other worlds, though the news is not always easy to decipher.

All the celestial bodies are in motion amid the multitudinous waves of space. Something can be learned respecting their motions by studying the waves. If a strong swimmer were stemming a series of long, rolling waves, their crests would pass him in more rapid succession than if he were at rest; if, on the other hand, he reversed his course, so that waves overtook instead of meeting him, their crests would pass in slower succession. One can easily conceive how, if he knew the exact rate at which the crests would pass him—so many exactly per minute—were he at rest, their slower or more rapid succession might indicate how fast he himself was moving, either from or toward them. If he were quite unconscious of his own motion, the effect would be simply that the distance from crest to crest would seem to be diminished in one case, lengthened in the other—that is, the waves narrowed or widened. Similarly with the aërial waves which produce sound. They are seemingly shortened when the source of sound is approaching, whether by its own motion or the hearer's, and lengthened when the source of sound is receding. In the former case the tone of the sound is made more acute, in the latter graver than it really is. This is strikingly illustrated when a swift train rushes past a station, the whistle sounding all the time, for there is a perceptible lowering of the whistle's note as the engine passes a hearer on the platform. While the train is appproaching him, he hears a note somewhat sharper than the true note of the whistle; after it has passed he hears a note somewhat flatter than the true note. Still more obvious, even to non-musical ears, is the corresponding change when two trains pass each other. In America, where a hideously-clanging engine-bell is used, the change is very remarkable, insomuch that a person unfamiliar with the arrangement actually adopted would suppose a different bell was rung the moment the engine passed the hearer.

Light traveling also in waves, it is obvious that a similar effect must be produced by approach or recession, if only the rate of motion is sufficiently rapid. The swimmer of my first illustration must have

a velocity comparable with that of the water-waves, or no change will be observed. The trains of the second illustration must have a velocity comparable with that of the aërial waves producing sound, or no change of tone will be produced. And in like manner a star or other celestial body must be approaching us, or receding from us, with a velocity comparable with that of the ethereal waves producing light, or no change of color will be produced, the color of light corresponding with the tone of sound. Unfortunately for this purpose, though most fortunately in other respects, light travels at so enormous a rate that even the swiftest motions of the heavenly bodies seem rest by comparison. What, for instance, is the rush of even Newton's comet past its point of nearest approach to the sun, though at the rate of more than 300 miles per second, to the flight of light over nearly 200,000 miles in the same time? Very much as the movement of a person taking only six steps a minute, each less than half a yard long, to the rush of the swiftest express-train. Yet astronomers have undertaken to measure the approach and recession of stars, moving—in some cases—with less than a tenth part of that comet's motion, and whose velocity, therefore, sinks into still more utter insignificance by comparison with that of light.

Secchi claims (but not justly) to have first invented and applied the method used for this purpose, which consists in noting whether some known line of the spectrum of a heavenly body changes in position—either by moving toward the violet end of the spectrum, which would imply approach, or by moving toward the red end, which would imply recession. Of course, the method is exceedingly delicate and difficult, involving a number of details which would be quite unsuited to these pages; but that, in principle, is its nature. Secchi tried the method, and failed to get any results from it, announcing his unsuccessful attempt in March, 1868. "Then," he says, "Mr. Huggins retried (*reprit*) the method, announcing in April, 1868, the discovery that Sirius is receding at the rate of twenty miles per second." Secchi should know well, however, that our great spectroscopist did not achieve this success in the few weeks between Secchi's announcement of failure and Huggins's announcement of success. Months had elapsed, during which Huggins had been struggling with this difficult problem. If the enunciation of the method gave claim to the credit of its successful application, I myself could advance a stronger claim than Secchi's, for in an essay in *Fraser's Magazine* for January, 1868, I definitely indicated the nature and value of the method. But I would rather refer to the circumstance as enabling me to support Huggins's assertion that he was observing by this method for months before Secchi announced his own failure, for immediately on the appearance of my essay I received a letter from Dr. Huggins, mentioning (in confidence, until his paper should be published) that he had been for some time striving for success

by the method I had described. This was nearly three months before Secchi's paper appeared. Subsequently Huggins observed by this method a number of stars, some of which he found to be receding from us, others approaching us.

Recently, however, the method itself has been called in question —first, by Van der Willigen, for reasons professedly mathematical, but unsound; secondly, by Secchi, because of his failure to see what Huggins has observed. Secchi had once based his attack on his failure to detect by this method the effects of the sun's rotation. As the sun's equator is spinning swiftly round, it is necessarily approaching on one side and receding on the other. By some amazing miscalculation, never yet explained, Secchi made the rate of this motion many times larger than it really is—so large, in fact, that the method we have described should have exhibited the sun's whirling motion. Small as the effect really is—amounting, in fact, only to a relative motion of about two and a half miles per second—Huggins did not despair of recognizing it; but he failed, though he used a double and twice-acting battery of prisms (the invention of the present writer—so far, at least, as its duplex character was concerned) made by Mr. Browning. Mr. Christie, of Greenwich, after resolutely grappling with the work of determining star-motions by this method, and in the main confirming Huggins's results, succeeded in recognizing by its means the known motions of Venus toward or from the earth, in various parts of their respective orbits. This was a great triumph, and more than met Secchi's objections. But Prof. Young has gone, for the present, ahead of all other observers by this method. Availing himself of a beautiful extension of spectroscopic powers, due to Dr. Rutherfurd, of New York, he has succeeded in unmistakably recognizing the effects of the sun's motion of rotation by the spectroscopic method. Young has made the observations so satisfactorily that he relies even upon the difference between his results and the measured rate of the sun's rotation. He finds the sun's atmosphere (whence, of course, the spectral lines come) to be traveling faster than the sun's visible surface. To use his own words, "The solar atmosphere really sweeps forward over the underlying surface, in the same way that the equatorial regions outstrip the other parts of the sun's surface." The difference of rate is about ten miles per minute. For my own part, I doubt very much whether so small a difference can be indicated by this method. But even if we regard this part of Young's work as not yet proved—nay, even if we go further, and accept nothing more than the bare recognition of the sun's rotation by the new method—he must be congratulated on having effected the most delicate piece of spectroscopic observation yet achieved by man. He has placed beyond doubt or cavil a method of motion-measuring the most remarkable yet invented, and likely, as instrumental means improve, to be most fruitful in results of astronomical interest and importance.

NATURE AND LIFE IN LAPLAND.[1]

By C. CHAMBERLAIN.

NONE who have had experience of travel in Swedish Lapland are likely to deny to it the charms of perfect freshness and originality. The almost primitive character and habits of the people, the singular conditions of their life, the unique splendor of the scenery, the bright intoxication of the air, and the glory of the arctic sunsets, are all a constant source of pleasure and surprise. For the angler there is almost unlimited trout and grayling fishing, with possibilities of salmon; and for the sportsman abundance of ptarmigan, willow grouse, hares, and wild-fowl of all descriptions; while the cost of living, not indeed sumptuously, but sufficiently well, may be covered by two or three shillings a day. Unfortunately, these advantages can only be reached by routes so little tempting to the ordinary tourist that it appears from the visitor's book at Quickjock that only three hundred persons in twenty years have braved the discomforts of the approach. Now, however, that Norway is becoming hackneyed ground, and that all its available streams are rented and preserved, it is possible that the attractions of Lapland may yet counterbalance the well-founded objections to the gulf of Bothnia. At the present time the trip cannot be recommended to ladies, unless they are willing to put up with more than the usual inconvenience and discomfort of out-of-the-way travel; but for men, willing to rough it a little, there is no hardship or difficulty greater than those with which most sportsmen must be already familiar.

Stockholm, the starting-point of the expedition, may be reached direct by Hull and Gothenburg; or, if the land-route be preferred, through Calais, Cologne, and Hamburg, and thence, either through Jutland to Friedrickshavn, and across the Cattegat to Gothenburg, or by Kiel and Korsoer to Copenhagen, and thence by Malmö to Stockholm. For bad sailors the last route is to be preferred, as in the other cases the traveler must make the acquaintance of either the Skaggerack or the Cattegat, or of both; and he will probably find that their names are not rougher than their waters, and that they are in fact the most diabolical cross-seas on the face of the globe. The captain of the little steamer which plies between Gothenburg and Friedrickshavn, who has spent the greater portion of his life in ocean-ships, informed us that he never dared to go below when the Cattegat was rough, but found his only safety from sickness in the fresh breeze on deck.

[1] From an article entitled "A Visit to Lapland, with Notes on Swedish Licensing," *Fortnightly Review*, December, 1876.

The distinctive beauty of Stockholm is in its situation. Built partly on islands in Lake Malar, it is intersected in every direction by the waters of the lake and of the Baltic, and, with its busy quays, broad streets, handsome buildings, pleasant gardens, and clear atmosphere, is certainly one of the brightest and most charming capitals in Europe. The streets are still enlivened by the gay costumes of the peasants, especially those of the nearest provinces; it is said, however, that their use is gradually dying out before the advance of railroads and other enemies of the picturesque.

The Swedes are undoubtedly a fine race; many of the men are very tall, and the women are almost universally refined-looking and graceful in their carriage. A crowd of Swedes might at any time be mistaken by an Englishman for a crowd of the better sort in his own country; and in character there is the same resemblance to a high average English standard. The middle and trading classes have great sympathy with the English nation and its institutions, and are ready at all times to express and prove it; the aristocracy and higher ranks of society are more inclined to favor French manners and customs, but this is due to the influence of the court and to the origin of the royal family. Every educated Swede reads and probably speaks English well, and with very slight, if any, foreign accent. English newspapers and books of all kinds are largely read, and English literature is a prominent branch of study at the high or middle-class schools, of which, as of all other educational institutions, there is an ample supply in Sweden. All along the coast of the gulf of Bothnia, in every little town of a few hundred, or at most of two or three thousand, inhabitants, there is a large school of this description, with a full staff of masters, *lektors*, and assistants, provided according to a fixed scale, and forming part of the general organization for national instruction. We met several of these teachers, and found them extremely well-informed and intelligent men, speaking English, French, and German, and accepting for the communication of these acquirements salaries which would be deemed totally inadequate in any other and richer country. They were all home-taught, by books and not *viva voce*, and hence, though well qualified to translate English into Swedish, they found it more difficult to reverse the process and to interpret their thoughts into elegant English. "The weather is deplorable," said one of these gentlemen; "it makes for the melancholy, and influences on the humors."

The fees charged in the schools are moderate, and such as to induce a general acceptance of the educational advantages offered by the class for whom they are intended. Primary education in Sweden is free and compulsory, though it is seldom necessary to recur to the interference of the magistrates. The Swedes cannot be made to understand the beauty of our English system, by which a national service, undertaken on the distinct ground of its importance to the

whole community, is made unpopular by a charge extorted from the persons whose ready and voluntary acceptance of the service is the object desired. They argue that the state, as a whole, is bound to secure to all its citizens the opportunity of acquiring at least the elementary knowledge which is requisite for its security and general well-being, and that it is the function of the state to offer this instruction free of charge before it attempts to compel any individual to avail himself of it. They attribute the almost universal prevalence of primary instruction in their country to the existence of these free schools, and point to their wide popularity as sufficient evidence of the fallacy of the proposition, so often taken for granted in England, that the poor do not value education which is paid for out of the general taxation of the community.

Steamers leave Stockholm for Haparanda, at the head of the gulf of Bothnia, two or three times a week, calling on the way at the ports on the west coast. Against a head-wind these boats roll and pitch in an extremely provoking fashion; but, during the summer months, the voyage is generally a smooth one. The boats carry stores to the towns on the route, and bring back tar, which, with wood, and iron from the mines of the great Gellivara Company—now the sole property of an English merchant—constitute the chief trade of the gulf. The coast navigation is extremely intricate and difficult, the steamer winding its way for hours through the fiords and among innumerable rocky islets. On one occasion we bumped over a sunken rock, and, if one may judge by the composure of the captain, this must be no infrequent occurrence, though it smashed all the crockery laid out in the saloon and greatly alarmed the passengers. At night, and on the occasion of a fog, progress is impossible, and the steamer is brought-to and anchored till daylight or clear weather.

Our destination was Luleä, which is reached in about seventy-two hours from Stockholm, and is a town of some 2,000 inhabitants, situated at the mouth of the great river of the same name. The harbor, after the difficulties of the entrance are surmounted, is a fine one, and many English and other ships lie here, loading timber; it is floated down the river from the forests, and cut into planks or made up into frames for doors and windows at the saw-mills in the town and neighborhood.

The houses are almost entirely built of wood, and are in many cases shops and warehouses, as well as dwelling-houses, although there is little display of goods in the windows. There is a large school, attended by the youths from all the surrounding district, as well as by those resident in the town itself. Luleä is the seat of the government of the province of Norbotten, which includes the whole of Lapland, and has a population of 80,000, scattered over 1,932 square miles of country. The governor, who has no sinecure, being required to visit personally his immense district several times a year,

is provided with an official residence and a salary of 12,000 Swedish crowns, or about £650 per annum.

On arriving at the inn, which is good and clean, and makes up some forty beds, one is struck with a peculiarity of all similar places in Sweden, namely, the apparent indifference to visitors exhibited by the proprietor. No head-waiter, with attendant circle of porters and chambermaids, awaits the arrival of the guest. The luggage is put down at the entrance, and the traveler must seek for himself his rooms and the information he requires; while the landlord, with his hands in his pockets, regards his efforts from a window with languid curiosity. There is no intentional incivility, but it appears not to be the custom to welcome the coming guest, although to speed the parting guest there is abundance of hand-shaking and hearty good wishes. The curious custom of the Smörgos prevails at these inns, and indeed everywhere throughout Sweden; it consists in a standing refreshment provided at a side-table free of charge, and comprising bread and butter, cheese, caviare, dried fish and reindeer-flesh, sausages, and other similar delicacies, to be taken immediately before each regular meal, and washed down with *branvin* and other neat spirits. In connection with this performance the Swedes have an objectionable habit, which may be called the community of forks, as the same implement passes rapidly from mouth to mouth and from dish to dish; the rights of private property are flagrantly disregarded.

From Luleä a succession of three small steamers, each making its passage to the bottom of considerable rapids, carry the traveler some ninety miles up the Luleä River to its junction with the Little Luleä at Storbachen, and across the frontier of Sweden into Lapland, which commences about ten miles below the confluence. The scenery is extremely striking, especially toward the end of the road. The river is a noble stream, never narrower than the Thames at Westminster, and expanding at intervals into broad stretches of water which, shut in by the windings of the river, present the appearance of considerable lakes. The banks are lined with the pine-forests for many miles, and the dark green of the firs and larches is varied by the brighter foliage and silver bark of the birches, which grow in considerable numbers among the other trees. At intervals, gradually getting longer as the distance from Luleä increases, the villages or settlements of the Swedish farmers break the uniformity of the scene, and the wooden houses and out-buildings, painted bright red, with the windows and doors picked out in white, and surrounded by small clearings with patches of yellow barley and green pasture, stand out brightly against the sombre background of the forests, and give animation and warmth to the landscape. It is difficult to convey the peculiar fascination of this scenery. It is due especially to the sharpness and contrast of color, the bright clear blue of the sky giving definiteness to the outlines of the trees and hills, and bringing

into marked relief all the incidents of the view. There is something bracing in the very appearance of the landscape, to which the noble river is an ever-fitting foreground.

At Storbachen the river has to be exchanged for the road, and a country cart holding two persons, and with or without an apology for springs as chance may determine, carries the tourist along the banks of the Little Luleä to Jockmock, a distance of some thirty miles. This drive is in itself a unique experience. The road after wet weather is cut up into deep ruts, in and out of which the cart plunges with a violence most discomforting to its occupants, who are bruised and pounded without the possibility of resistance. It must be admitted that the process detracts from the pleasure of the excursion, which in other respects is extremely interesting. The route lies for the whole day through the almost trackless forests. Hardly a human being is to be met in these immense solitudes, and the silence is only broken occasionally by the note of some strange bird or the movement of the wind through the trees. In many places forest-fires have ravaged the country for great distances, and everywhere there is a vista of blackened stems or falling trunks. In contrast to this desolation, where the fire has not passed, the ground is carpeted with the most luxuriant mosses and lichens in all the tints of green and red and yellow, while an occasional clearing, though at very rare intervals, relieves from time to time a sense of utter loneliness by the evidence it gives of the neighborhood of human beings.

The forests cover nearly one-half of the whole surface of Sweden, and constitute an important part of the wealth of the country and the revenue of the Government. In past times they were very carelessly managed, and in many cases were sold outright and without conditions to merchants, who ruthlessly cut down the timber with sole regard to their immediate interests. The pine is of very slow growth, increasing only one inch in diameter in ten years, and reaching twelve to fourteen inches in a century; and the wholesale destruction of young wood has left large tracts desolate and unprofitable for an indefinite period. The soil is excessively poor, consisting of sand with the thinnest possible coating of vegetable mould, so that no ordinary cultivation is possible.

Now the forests are strictly looked after, and no land is sold; but the right of cutting wood, limited to trees of ten inches and upward in diameter, is let for a term of years and by tender, at so much per tree. In the remote districts the royalty is about 1*s.* 3*d.* per tree, and the lessees have in addition to carry out works for deepening the rivers and keeping them clear of all obstructions. Twenty years ago the value of trees on the ground was not more than threepence or fourpence apiece.

From Jockmock to the end of the journey at Quickjock the mode of traveling and the scenery are again changed. The head-waters of

the Little Luleä are a series of large lakes, from six to thirty miles long, and varying in breadth from two miles to seven or eight. These in turn are fed by two mountain-rivers, which join their floods at Quickjock, and pour the united stream into the uppermost lake. They are traversed in long, open boats made of very thin wood, and rowed by two or three men, according to the weight of luggage and the length of the journey. These boats are unprovided with seats, and the passengers have to squat at the bottom back to back, or crowded side by side; and, as very little movement would be sufficient to swamp so frail a craft, the limbs get cramped and stiffened, and the journey becomes very fatiguing. With a high wind the broadest lakes become rough and dangerous, and on one occasion we shipped so much water that it seemed doubtful whether our expedition would not come to an untimely end. Each lake is connected with the next by strong rapids, in some cases rising into small waterfalls, and to avoid these it is necessary to disembark, when the luggage is carried on the shoulders of the rowers through the pine-forests to the next lake. Throughout this part of the trip the silence can almost be felt, and becomes at last oppressive. No living thing is seen for hours except occasional flights of wild birds, or a solitary heron disturbed by the passage of the boat. Hills, gradually developing into mountains, and finally covered with snow as the neighborhood of Quickjock is reached, shut in the scene, and the slopes of these are covered almost entirely with stunted pine, the birch having nearly disappeared. There is, however, no lack of color, as the firs in the sunlight present many shades of the darker greens intermingled with a rich brown where some disease appears to have attacked the trees. A large sweep of pine-forest thus spread out in an amphitheatre of hills, and seen from a great distance, might be mistaken for an expanse of heather and fern, browned by the autumn rains and sun, though of course the brighter purples are absent from the Lapland view.

In the summer months there is perpetual daylight in all these regions, and the midnight sun is visible for some time in June. When we were there, in September, it was light till nine or ten o'clock, and never absolutely dark. The sunsets were most gorgeous, dark masses of purple clouds being lit up with the intensest hues of gold and crimson as the sun went down behind them, a glowing ball of fire. On one occasion the effect was heightened by the appearance of the eastern sky, which shaded off from deepest rose at the zenith, through delicate gradations of pinks and purples, into a lovely pale, pure blue, in the midst of which the full autumnal moon shone gloriously.

The fishing in the lakes is exceedingly good, and very large trout, and even salmon, may be caught with the minnow and other spinning bait. For fly-fishing the best places are the rapids between the lakes, through which the boat is screwed in and out in an extremely clever and dexterous way by the boatman, who takes advantage of the shel-

ter of every rock and stone as he passes from one to the other, while the stream shoots by. In favorable weather an angler may easily land a hundred-weight of trout and grayling in a day's sport, the fish running from half a pound to two pounds in weight. The flies sold by the London makers should be supplemented by some of a smaller size for bright weather and clear water; one with a body of yellow silk and grayish-brown wings is said to be very killing.

The distance from Jockmock to Quickjock, the two principal villages on the route, is about ninety miles, and is performed in three days. Each of these places has a church, a school, and a post-office, and Jockmock is said to have a shop, though we could not find it. They are really collections of small wooden huts, vacant during the summer months, but occupied in the long winter by the Lapps, who then come down from the mountains with their reindeer. Quickjock especially is in a delightful situation, facing a beautiful lake, and sheltered by mountains of noble outlines and grand proportions. At Jockmock there are some fine falls, not unlike the Rheinfalls at Schaffhausen, though in a very different setting. The resting-places or stations between these two villages are not inns in the usual sense of the word, but the houses of the Swedish settlers or immigrants into Lapland, one of which at each settlement is destined for the reception of the occasional guests.

These settlements consist of two or perhaps four houses, with the necessary out-buildings, and seem generally inhabited by the several members of the same family. Some of them have existed a considerable time, and are occupied now by the grandchildren or great-grandchildren of the original settlers. Originally the Government granted free gifts of land, but they have now ceased to do this, and the number of the settlers does not appear to be receiving many additions from outside. The houses usually consist of two or more large rooms on the ground-floor with lofts above, and vast chimney-hearths in one corner, in which the logs of pine, some two or three feet in length, are piled upright when a fire is wanted; being lit, they burn up in a few minutes into a roaring fire which gives out an intense heat. The family live chiefly in the kitchen, and this and the guest-chamber are about twenty or thirty feet square, and furnished with a kind of sofa-bedstead which pulls out so as to afford a sleeping accommodation of about five feet six inches by three feet. The kitchen itself is not over-clean, nor are the personal habits of the people without reproach in this respect; yet the guest-chamber, the linen, and the crockery, leave nothing to be desired.

The houses are surrounded by a small clearing, where the settlers cultivate for their own consumption sufficient oats and other grain, hay, and potatoes. They sow their corn in June, and so rapid is the growth under the influence of the lengthened days that they reap the harvest in six or seven weeks afterward, and sometimes get two crops

in their short season. The cultivation is restricted to the actual wants of the settlement, as the difficulty of transit precludes the possibility of a market for the surplus. Cattle and ponies, and sometimes sheep and poultry, are kept at each station, but the food of the family is limited to fish—which is dried for winter use—milk, black or rather brown flat bread, and dried reinflesh, with an occasional change in the shape of game or wild-fowl killed on the hills or lakes. Everywhere, even in the poorest houses, the most excellent coffee is obtainable; the green berries being roasted over the fire and ground whenever a cupful or more is wanted.

In the winter, when the lakes and rivers are all frozen, and the ground is covered three or four feet deep with hard snow, the settlers go long distances on snow-shoes and in sledges, and bring up from Luleä what stores they may require. The money for such purchases is gained by winter labor in the forests, where the trees are felled and dragged to the water's edge, to be thrown in and floated down to Luleä when the ice breaks up. At this work a team of one horse and two men can earn about 40*s.* a week, which is considered large wages in this part of the world. The legal tariff for a boat in summer is one kronor (1*s.* 1½*d.* English) for each man for seven miles, with no allowance for back fare; and a small *dricks penningar*, or *pour-boire*, added to this will make them supremely grateful, and insure the generous donor many hearty shakes of the hand.

The settlers cannot afford to be ill, as the nearest doctor lives at Luleä, almost a week's journey from Quickjock. In ordinary cases they depend on their own resources, but in any serious illness the Luleä medico is sent for and is obliged to attend, being paid a small salary of £200 a year by the Government on this condition. Midwifery is performed by women. Crimes of any kind seem to be very rare; and though every settler carries a most ugly-looking dagger-knife suspended from his belt, its use appears to be confined to purely pacific purposes. The most common offenses are against the forest regulations, and the observance of these is superintended by an officer who has his headquarters at Jockmock. On *fête* days, at this latter village, a patrol is selected by the Governor of Luleä from among the steadiest of the settlers, and to him the preservation of order is intrusted.

The men are physically a fine race, and are generally honest and industrious, with an air of independence and straightforwardness. Like the poorer Swedes elsewhere, they are greatly given to the use of tobacco in all forms; and besides smoking and chewing in the usual approved methods, they actually eat large quantities of snuff, helping themselves, as the Highlanders do, with a horn spoon from a box. The women have pleasant faces, with rather refined expression. There is a strong family resemblance among them, and the type consists in large gray eyes, brown hair, rather fair complexions, a free carriage,

and not ungraceful figure, though with full waists and large hands and feet. The older women look worn, but never have the haggish and almost brutalized look which is not uncommon in old women in other countries who have led hard, out-door lives. The general expression of countenance is somewhat pathetic, though they seem contented with their strange, solitary, and joyless life; and we could never get any of them to confess that they would care to change it, nor even to complain of what, as it appeared to us, must be the terrible monotony and hardship of the long, dark winter. In looking at these settlements and considering the nature of the life we seemed to understand more clearly the position and circumstances of the immigrants who are gradually pushing farther and farther along the shores of the great rivers of the American Continent, and carrying into the solitudes of the immense forests of the West the proofs of Anglo-Saxon courage, endurance, and pertinacity.

At some of the stations we saw specimens of the original inhabitants of the lands within the arctic circle, in the persons of Lapp men and women of uncertain age, about four feet high, and dressed in skins, with blue conical caps on their heads. In Norway it is said that the Lapps are looked upon and treated as an inferior race, the pariahs of the North; but in Swedish Lapland there is no appearance of such distinctions. The comfort and even safety of the settlers depend so much on their good relations with their neighbors that they have remained on terms of equality and friendship. Intermarriages are not uncommon, and many of the present settlers show signs of the mixture of the races.

The population of Swedish Lapland is said to include 4,000 persons of true Lapp race, and in some districts this number is increasing. The children born in the mountains die fast, but those who remain in the villages are healthy. Provision is made for their instruction, and in common with the children of the Swedes they all learn to read and write, though, judging by the absence of books at the settlements, they reap little advantage from their instruction. The Lapps were converted to Lutheranism some hundred years ago, and are said to be strict religionists. At the present time some kind of revival is going on among them, a faint reflex of the Moody and Sankey movement in this country and America.

They depend for their living entirely upon their reindeer, which they take up into the mountains all the summer, feeding them in the villages during the winter, when the rein-moss, which is their ordinary food, is no longer obtainable in the woods. This migration is rendered necessary by the habits of the reindeer, which must be near snow to keep in health. When on their summer excursions, the Lapps live in tents made of rein-skins, lying at night round a fire in the centre, a hole being left in the roof for the passage of the smoke. Their food consists of rein-flesh, fish, and game, and they keep a pot, like

the gypsies, constantly on the fire, into which are thrown all contributions in the way of edibles, which are thus stewed down together into a thick rich soup. In the winter they move about on their snow-shoes, in the management of which they are extremely adroit, shooting down the hills and in and out of the trees with immense swiftness and precision. On these shoes they hunt down both wolves and bears when these animals, which are now getting scarce, cross their path; they kill them with their spears and knives, getting a reward of fifty kronor from the Government for each head killed. The sale of spirits is strictly prohibited in Lapland, as some years ago their immoderate use was decimating the population; but kegs of *branvin* are still occasionally smuggled across the borders, and produced on the occasion of *fêtes* and holidays. The Lapps have shrewd, almost cunning faces, and, though small in stature, possess great bodily strength and endurance. Their habits are extremely dirty, and they appear never to change their clothes till they fall to pieces.

PHYSIOLOGY OF MIND-READING.

BY GEORGE M. BEARD, M. D.

IN the history of science, and notably in the history of physiology and medicine, it has often happened that the ignorant and obscure have stumbled upon facts and phenomena which, though wrongly interpreted by themselves, yet, when investigated and explained, have proved to be of the highest interest. The phenomena of the emotional trance, for example, had been known for ages, but not until Mesmer forced them on the scientific world, by his public exhibitions and his ill-founded theory of animal magnetism, did they receive any serious and intelligent study. Similarly the general fact that mind may so act on body as to produce involuntary and unconscious muscular motion was by no means unrecognized by physiologists, and yet not until the "mind-reading" excitement two years ago was it demonstrated that this principle could be utilized for the finding of any object or limited locality on which a subject, with whom an operator is in physical connection, concentrates his mind.

Although, as I have since ascertained, experiments of this kind had been previously performed in a quiet, limited way in private circles, and mostly by ladies, yet very few had heard of or witnessed them; they were associated in the popular mind very naturally with "mesmerism" or "animal magnetism," and by some were called "mesmeric games." The physiological explanation had never been even suggested; hence the first public exhibitions of Brown, with his brilliantly successful demonstrations of his skill in this direction, were

a new revelation to physiologists as well as to the scientific world in general.

The method of mind-reading introduced by Brown, which is but one of many methods that have been or may be used, is as follows:

The operator, usually blindfolded, firmly applies the back of the hand of the subject to be operated on against his own forehead, and with his other hand presses lightly upon the palm and fingers of the subject's hand. In this position he can detect, if sufficiently expert, the slightest movement, impulse, tremor, tension, or relaxation, in the arm of the subject. He then requests the subject *to concentrate his mind* on some locality in the room, or on some hidden object, or on some one of the letters of the alphabet suspended along the wall. The operator, blindfolded, marches sometimes very rapidly with the subject up and down the room or rooms, up and down stairways, or out-of-doors through the streets, and, when he comes near the locality on which the subject is concentrating his mind, a slight impulse or movement is communicated to his hand by the hand of the subject. This impulse is both involuntary and unconscious on the part of the subject. He is not aware, and is unwilling, at first, to believe, that he gives any such impulse; and yet it is sufficient to indicate to the expert and practised operator that he has arrived near the hidden object, and then, by a close study and careful trials in different directions, upward, downward, and at various points of the compass, he ascertains precisely the locality, and is, in many cases, as confident as though he had received verbal communication from the subject. Even though the article on which the subject concentrates his mind be very small, it can quite frequently be picked out from a large number, provided the subject be a good one, and the operator sufficiently skillful. The article is sometimes found at once, with scarcely any searching, the operator going to it directly, without hesitation, and with a celerity and precision that, at first sight, and until the physiological explanation is understood, justly astonish even the most thoughtful and skeptical.[1] These experiments, it should be added, are performed in public or private, and on subjects of unquestioned integrity, in the presence of experts, and under a combination of circumstances and conditions for the elimination of sources of error that make it necessary to rule out at once the possibility of collusion.

The alternative is, therefore, between the actual transfer of thought from subject to operator, as has been claimed, and the theory of unconscious muscular motion and relaxation on the part of the subject, the truth of which I have demonstrated by numerous experiments.

One of the gentlemen with whom I have experimented, Judge Blydenberg, who began to test his powers directly after I first called

[1] In New Haven I saw Brown, before a large audience, march off rapidly through the aisle and find at once the person on whom the subject was concentrating his mind, although there was the privilege of selecting any one out of a thousand or more present.

public attention to the subject in New Haven, claims to succeed, even with the most intellectual persons, provided they fully comply with the conditions, and honestly and persistently concentrate their minds. One fact of interest, with regard to his experiments, is the exceeding minuteness of the objects that he finds. A large number of the audience empty their pockets on the table, until it is covered with a medley of keys, knives, trinkets, and miscellaneous small objects. Out of them the subject selects a small seed a little larger than a pea, and even this the operator, after some searching, hits precisely.

One may take a large bunch of keys, throw them on the table, and he picks out the very one on which the subject concentrates his mind.

Another fact of interest in his experiments is that, if the subject thinks over a number of articles in different parts of the room, and, after some doubt and hesitation, finally selects some one, the operator will lead him, sometimes successively, to the different objects on which he has thought, and will wind up with the one that he finally selected. He also performs what is known as the "double test," which consists in taking the hand of a third party, who knows nothing of the hidden object, but who is connected with another party who does know, and who concentrates his mind upon it. The connection of these two persons is made at the wrist, and the motion is communicated from one to the other through the arms and hands. The "double test" has been regarded by some as an argument against the theory that this form of mind-reading was simply the utilizing of unconscious muscular motion on the part of the person operated upon.

This gentleman represents that the sensation of muscular thrill is very slight indeed, even with good subjects; and, in order to detect it, he directs his own mind as closely as possible to the hand of the subject.

In all these experiments, with all mind-readers the requirement for the subject to concentrate the mind on the locality agreed upon is absolute; if that condition is not fulfilled, nothing can be done, for the very excellent reason that, without such mental concentration, there will be no unconscious muscular tension or relaxation to guide the operator.

Experiments of the following kind I have made repeatedly with the above-named gentleman:

A dozen or more pins may be stuck about one inch or half an inch apart into the edge of a table: I concentrate my mind on any one of these pins, telling no one. The operator enters the room, gets the general direction of the object in the usual way (*à la Brown*), and, when he has come near to the row of pins, he will limit the physical connection to one of his index-fingers, pressing firmly against one of mine, and in this way he soon finds the head of the pin on which my mind has been concentrated. The only limitation of area in the locality that can be found by a good mind-reader with a good subject is,

that two objects should not be so near to each other that the finger of the operator strikes on both at once. When I began the study of this subject, I supposed, even after the true theory of the matter had become clear to me, that very small objects and narrow areas could not be found in this way. Subsequent experiments showed that this supposition was erroneous. In a wide hall, in the presence of a large audience, where the subject had the right to think of any object he chose, Brown once found, after considerable searching, so limited an area as a capital letter in the title of a newspaper pinned up on the wall and barely within reach. About an hour after, in the same place, he found a very small vial out of quite a large number ranged in a row. Although reasoning deductively from the known relations of mind to body, I had established conclusively to my own mind that the so-called mind-reading was really muscle-reading, yet I could not believe, until the above-named experiments had been made, and frequently repeated, that it was possible for even the most expert operator to find such small objects; and no physiologist, I am sure, would have believed such precision in these experiments conceivable until his general deductions had been many times verified, and supplemented by observations in which every source of error was guarded against.

As already remarked, there are a variety of ways of making the physical connection between subject and operator. A lady with whom I am acquainted goes out of the room, and while she is absent an object is hidden. She returns, and two ladies, who know where the object is stand up beside her in the middle of the room and place both of their hands upon her body, one hand in front, the other behind; all three stand there for a moment, the two subjects who know where the object is, keeping their minds intensely concentrated on that locality. In a moment or so this lady who is to find the object moves off in the direction where it is, the other ladies with her still keeping their hands upon her, and in nearly all cases she finds it. This is accomplished by the unconscious muscular tension of the two ladies who know where the object is, acting upon the person of the lady who is seeking it.

This experiment I have repeated with a number of amateur performers, and in all cases with pretty uniform success. This method is easier, both to learn and to practise, than some of the others; it is also far less artistic, and is not at all adapted for the finding of very small localities. It illustrates, however, the general principle of mind acting on body producing muscular tension in the direction of the locality on which the thoughts are concentrated.

The relaxation, when the locality or its neighborhood is reached, is not so distinctly appreciated in this method of experimenting, which is sufficient, however, to enable the operator to get the right direction and to proceed until the corner or side of the room is reached; then, by a combination of manipulation and guess-work, she will, after

a few trials, get hold of the precise object hidden, or locality thought of. When the operator and subject are connected by the methods practised by Brown, it is possible to detect also the relaxation when the locality is reached, and, guided by this, the master in the art knows just when and where to stop, and, in very many cases, feels absolutely sure that he is right, and with a good subject is no more liable to error than he would be to hear wrongly or imperfectly if directed by word of mouth.

The special methods of muscle-reading here described may be varied almost indefinitely, the only essential condition being, that the connection between the subject or subjects is of such a nature as to easily allow the sense of muscular tension or relaxation to be communicated. Instead of two subjects, there may be three, four, or half a dozen, or but one. With a number of subjects the chances of success are greater than with one, for the twofold reason that the united muscular tension of all will be more readily felt than that of but one, and because any single subject may be a bad one—that is one who is capable of muscular control—while among a number there will be very likely one or more good ones. For these two reasons, amateurs succeed in this latter method when they fail or succeed but imperfectly after the method of Brown.

A method frequently used, although it is not very artistic, consists in simply taking the hand of the subject and leading him directly, or, as is more likely to be the case, indirectly to the locality on which his mind is concentrated.

J. Stanley Grimes[1] thus describes the performance of a mind-reader in Chicago: "I repeatedly witnessed similar performances with different experts in this branch and under circumstances where every element of error from intentional or unintentional collusion was rigidly excluded. At the request of the company the same young lady was again sent from the room and blindfolded, as on previous occasions. The gentleman requested the company to suggest anything they desired the subject should be willed to do, thus removing any possibility of a secret agreement to deceive between the parties. It was suggested that the young lady should be brought into the room and placed in a position with her face toward the north; that the gentleman should then place his fingers upon her shoulder, as before; that she should turn immediately to the *right*, facing the south, and proceed to a certain figure in the parlor-carpet; then turning to the west, she was to approach a sofa in a remote corner of the room, from which she should remove a small tidy, which she should take to the opposite side of the room, and place it upon the head of a certain young gentleman in the company; she was then to proceed to the extreme end of the parlor, and take a coin from the right vest-pocket of a gentleman, and return to the opposite side of the room, and place the coin in the *left* vest-

[1] "Mysteries of the Head and Heart," p. 297.

pocket of another gentleman named; she was then to remove the tidy from the head of the gentleman upon whom it had been placed, and return it to the *tête-à-tête* where she originally found it.

"I must confess to no little surprise when I saw the young lady perform, with the most perfect precision, every minute detail, as above described, and with the most surprising alacrity; in fact, so quick were her motions that it was with the greatest difficulty that the gentleman could keep pace with the young lady's movements."

I have seen a performer—who, though one of the pioneers in this art, is far less skillful than many with whom I have experimented—take a hat from the head of a gentleman in a small private circle, and carry it across the room and put it on the head of another gentleman; take a book or any other object from one person to another; or go in succession to different pictures hanging on the wall, and perform other feats of a similar character, while simply taking hold of the wrist of the subject. In the experiment described by Mr. Grimes the subject placed three fingers of his right hand on the shoulder of the operator. Note the fact that in all these experiments *direction* and *locality* are all that the mind-reader finds; the quality of the object found, or indeed whether it be a movable object at all, or merely a limited locality, as a figure in the carpet or on the wall, is not known to the mind-reader until he picks it up or handles it: then if it be a small object, as a hat, a book, or coin, or tidy, he very naturally takes it and moves off with it in the direction indicated by the unconscious muscular tension of the subject, and leaves it where he is ordered by unconscious muscular relaxation. In the great excitement that attends these novel and most remarkable experiments the entranced audience fail to notice that the operator really finds nothing but *direction* and *locality*.

I have said that various errors of inference, as well as of observation, have been associated with these experiments. A young lady who had been quite successful as an amateur in this art was subjected by me to a critical analysis of her powers before a large private audience. She supposed that it was necessary for all the persons in the audience to concentrate their minds on the object as well as those whose hands were upon her. I proved by some decisive experiments, in which a comparison was made with what could be done by chance alone, that this was not necessary, and that the silent, unexpressed will of the audience had no effect on the operator, save certain nervous sensations created by the emotion of expectancy. Similarly, I proved that, when connected with the subjects by a wire, she could find nothing, although she experienced various subjective sensations, which she attributed to "magnetism," but which were familiar results of mind acting on body.

Another lady, who is quite successful in these experiments, thought it was necessary to hide keys, and supposed that "magnetism" had something to do with it. I told her that that was not probable, and

tried another object, and found that it made no difference what the object was. She supposed that it was necessary that the object should be secreted on some person. I found that this also was not necessary. She does not always succeed in finding the exact locality at once, but in some cases she goes directly to it; she very rarely fails.

In order to settle the question beyond dispute whether unconscious muscular action was the sole cause of this success in finding objects, I made the following crucial experiments with this lady: Ten letters of the alphabet were placed on a piano, the letters being written on large pieces of paper. I directed her to see how many times she would get a letter which was in the mind of one of the observers in the room correctly by chance purely, without any physical touch. She tried ten times, and got it right twice. I then had her try ten experiments with the hand of the person operated on against the forehead of the operator, the hand of the operator lightly touching against the fingers of this hand, and the person operated on concentrating her mind all the while on the object, and looking at it. In ten experiments, tried this day, with the same letters, she was successful six times. I then tried the same number of experiments with a wire, one end being attached to the head or hand of the subject, and the other end to the head or hand of the operator. The wire was about ten feet long, and was so arranged—being made fast at the middle to a chair—that no unconscious muscular motion could be communicated through it from the person on whom she was operating. She was successful but once out of ten times. Thus we see that by pure chance she was successful twice out of ten times; by utilizing unconscious muscular action in the method of Brown she was successful six times out of ten. When connected by a wire she was less successful than when she depended on pure chance without any physical connection. In order still further to confirm this, I suggested to this lady to find objects with two persons touching her body in the manner we have above described. I told these two to deceive her, concentrating their minds on the object hidden, at the same time using conscious motion toward some other part of the room. These experiments, several times repeated, showed that it was possible to deceive her, just as we had found it possible to deceive other muscle-readers.

The question whether it is possible for one to be a good muscle-reader and pretty uniformly successful, and yet not know just how the trick is done, must be answered in the affirmative. It is possible to become quite an adept in this art without suspecting, even remotely, the physiological explanation. The muscular tension necessary to guide the operator is but slight, and the sensation it produces may be very easily referred by credulous, uninformed operators to the passage of "magnetism;" and I am sure that with a number of operators on whom I have experimented this mistake is made. Some operators

declare that they cannot tell how they find the locality, that their success is to them a mystery; these declarations are made by private, amateur performers who have no motive to deceive me, and whose whole conduct during the experiments confirms their statements. Other operators speak of thrills or vibrations which they feel, auras and all sorts of indefinable sensations. These manifold symptoms are purely subjective, the result of mind acting on the body, the emotions of wonder and expectancy developing various phenomena that are attributed to "animal magnetism," "mesmerism" or "electricity"—in short, to everything but the real cause. I have seen amateurs who declared that they experienced these sensations when trying without success to "read mind" through the wires, or perhaps without any connection with the subject whatever. Persons who are in the vicinity of galvanic batteries, even though not in the circuit, very often report similar experiences.

The facts which sustain the theory that the so-called mind-reading is really muscle-reading—that is, unconscious muscular tension and relaxation on the part of the subject—may be thus summarized:

1. Mind-readers are only able to find *direction* and *locality*, and, in order to find even these, they must be in physical connection with the subject, who must *move* his body or some portion of it—as the fingers, hand, or arm. If the subject sits perfectly still, and keeps his fingers, hand, and arm, perfectly quiet, so far as it is possible for him to do so by conscious effort, the mind-reader can never find even the *locality* on which the subject's mind is concentrated; he can only find the *direction* where the locality is. Mind-readers never tell what an object is, nor can they describe its color or appearance; *locality*, and nothing more definite than locality, is all they find. The object hidden may be a coin or a corn-cob, a pin or a pen-holder, an elephant's tusk or a diamond-pin—it is all the same. Again, where connection of the operator with the subject is made by a wire, so arranged that mass-motion cannot be communicated, and the subject concentrates his mind ever so steadily, the operator does just what he would do by pure chance, and no more. This I have proved repeatedly with good subjects and expert performers.

2. The subject can successfully deceive the operator in various ways—first of all, by using muscular tension in the wrong direction, and muscular relaxation at the wrong locality, while at the same time the mind is concentrated in the right direction. To deceive a good operator in this way is not always easy, but after some practice the art can be acquired, and it is a perfectly fair test in all experiments of this nature.

Yet another way to deceive the mind-reader is, to think of some object or locality at a great distance from the room in which the experiments are made, and, if there be no ready means of exit, the performer will be entirely baffled. I am aware that some very surprising

feats have been done in the way of finding distant out-of-door localities by muscle-readers, but in these cases there has usually been an implied understanding that the search was to be made out-of-doors; muscle-readers have thus taken their subject up and down stairs or from one room or hall into another, and out-of-doors until the house or locality was reached.[1]

Another way in which deception may by practised is for the subject to select some object or locality on the person of the muscle-reader. This object may be a watch, or a pocket-book, or a pencil-case, or any limited region of his clothing, as a button, a cravat, or wristband. If such a selection be made, and the method of physical connection above described be used, the experiment will be a failure, provided the muscle-reader does not know or suspect that an object on his own person is to be chosen. Similarly, if the subject selects a locality on his own person, as one of the fingers or finger-nails of the hand that connects with the muscle-reader. When such tests are used, there is not, so to speak, any leverage for the tension of the arm toward the locality on which the mind is concentrated, and the muscle-reader either gets no clew, or else one that misleads him.

3. When a subject, who has good control over his mental and muscular movements, keeps the arm connected with the operator *perfectly stiff*, even though his mind be well concentrated on the hidden object, the operator cannot find either the direction or the locality. This is a test which those who have the requisite physical qualifications can sometimes fulfill without difficulty.

Here I may remark that the requirement to concentrate the mind on the locality and direction sought for all the time the search is being made is one that few, if any, can perfectly fulfill. Any number of distracting thoughts will go through the best-trained mind of one who, in company with a blindfolded operator, is being led furiously up and down aisles, halls, streets, and stairways, fearful each moment of stumbling or striking his head, and followed, it may be, by astonished and eager investigators. And yet these mental distractions do not seem to interfere with the success of the experiment unless the arm is kept studiously rigid, in which case nothing is found save by pure chance. The best subjects would appear to be those who have moderate power of mental concentration and slight control over their muscular movements. Credulous, wonder-loving subjects are sometimes partially entranced through the emotions of reverence and expectation; with subjects in this state, operators are quite sure to succeed.

[1] In Danielsonville, Connecticut, Brown, after an evening's exhibition in which his failures had been greater than usual (the intelligent committee having the matter in charge being prepared by previous discussion of the theory of unconscious muscular motion), took a subject, and led him from the hotel in the darkness through the streets, to some rather out-of-the-way building on which the subject had fixed his mind. A somewhat similar exploit is recorded of Corey, a performer in Detroit.

4. The uncertainty and capriciousness of these experiments, even with expert operators, harmonize with the explanation here given. Even with good subjects all mind-readers do not uniformly succeed; there is but little certainty or precision to the average results of experiments, however skillfully performed. An evening's exhibition may be a series of successes or a series of failures according to the character of the subjects; and even in the successful tests the operator usually must try various directions and many localities, sometimes for ten or fifteen minutes, before he finds the locality sought for; cases where the operator goes at once in the right direction, stops at the right locality, and *knows* when he has reached it, are exceptional.[1]

5. Many of those who become expert in this art are aware that they succeed by detecting slight muscular tension and relaxation on the part of the subject.

Some operators have studied the subject scientifically, and are able to analyze with considerable precision the different steps in the process. In the minds of many this fact alone is evidence adequate to settle the question beyond doubt.

6. A theoretical and explanatory argument is derived from the recent discovery of motor centres in the cortex of the brain.

I was repeating the experiments of Fritsch and Hitzig at the time when my attention was first directed to the remarkable exhibitions of Brown, and the results of my studies in the electrical irritation of the brains of dogs and rabbits suggested to me the true explanation of mind-reading before any opportunity had been allowed for satisfactory experiments.

The motto "when we think we move," which I have sometimes used to illustrate the close and constant connection of mind and body, seems to be justified by these experiments on the brain, and may assist those who wish to obtain a condensed statement of the physiology of mind-reading. Taking into full consideration the fact that all physiologists are not in full accord as to the interpretation to be given to these experiments, whether, for example, the phenomena are due to direct or reflex action, still it must be allowed, by all who study this subject experimentally, that thought-centres and muscle-centres are near neighbors, if not identical.[2]

[1] The popular theory to account for these failures is the weariness or exhaustion of the operator; but both in New York and in New Haven it was observed that Brown met with his most brilliant successes in the latter part of the evening, the reason being that he happened then to have better subjects.

[2] From an editorial in the *Boston Medical and Surgical Journal* (September 23, 1875), referring to the mind-reading exhibitions, and accepting the explanation here given, I make the following extract:

"The whole performance seems to us to furnish good illustrations of one or two well-known principles of great physiological interest. Of these the most important is one that finds at once support and application in the modern doctrine of the nature of aphasia

In all these experiments it should be observed there is no one muscle, there is no single group of muscles, through which this tension and relaxation are developed; it is the finger, the hand, the arm, or the whole body, according to the method employed. Among the various methods of making connection between the subject and operator are the following:

1. The back of the subject's hand is held firmly against the forehead of the operator, who, with his other hand, lightly touches the fingers of the subject's hand. (Brown.)

This is, undoubtedly, the most artistic of all known methods.

2. The hand of the operator loosely grasps the wrist of the subject.

This is a very inartistic method, and yet great success is oftentimes attained by it.

3. One finger of the operator is applied to one finger of the subject, papillæ touching papillæ.

This is a modification of the first method; by it exceedingly small objects or localities are found.

4. The operator is connected in the usual way with a third party who does not know the locality thought of by the subject, but is connected with the subject by the wrist ("double test").

In this experiment, which astounded even the best observers, the unconscious muscular motion was communicated from the subject to the arm of the third party, and through the arm of the third party to the operator.

5. Two, three, or more subjects, who agree on the locality to be thought of, apply their hands to the body of the operator in front and behind.

This method is excellent for beginners, and the direction is easily found by it; but it is obviously not adapted for the speedy finding of small objects; it is frequently used by ladies.

6. The hand of the subject lightly rests on the shoulder of the operator.

and kindred disorders; namely, that the thought, the conscious mental conception, of an act, differs from the voluntary impulse necessary to the performance of that act only in that it corresponds to a fainter excitation of nervous centres in the cortex cerebri, which in both cases are anatomically identical.

"Thus, in certain forms of aphasia the power to think in words is lost at the same time with the power of speech. Some persons think definitely only when they think aloud, and it would readily be believed in the case of children and uneducated persons that the ability to read would often be seriously interfered with if they were not permitted to read aloud. Similarly, a half-premeditated act of any kind slips often into performance before its author is aware of the fact. Further, there is reason to think, from the experiments of Hitzig, that these same centres may be excited by the stimulus of electricity so as to call out some of the simpler coördinated movements of the muscles on the opposite side of the body.

"Applying, now, this principle to the case in hand, it will be evident that for the person experimented with to avoid giving 'muscular hints,' of either a positive or a negative kind, would be nearly impossible."

In all these methods the operator is usually blindfolded, so that he may get no assistance from any other source than the unconscious muscular action of the subject.

The movements of the operator in these experiments may be either very slow, cautious, and deliberate, or rapid and reckless. Brown, in his public exhibitions, was very careful about getting the physical connection right, and then moved off very rapidly, sometimes in the right direction, sometimes in the wrong one, but frequently with such speed as to inconvenience the subject on whom he was operating. These rapid movements give greater brilliancy to public experiments and serve to entrance audiences, but they are not essential to success. They serve, no doubt, in many cases, to bewilder or partially entrance the subject, and thus to render him far more likely to be unconscious of his own muscular tension and relaxation through which the operator is guided.

The power of muscle-reading depends mainly, if not entirely, on some phase of the sense of touch. Dr. Hanbury Smith tells me that a certain maker of lancets in London had acquired great reputation for the superiority of his workmanship. Suddenly, there was a falling off in the character of the instrument that he sent out, and it was found that his wife, on whom he had depended to test the sharpness of the edge on her finger or thumb, had recently died.

That the blind acquire great delicacy of touch has long been known; Laura Bridgman is a familiar illustration. Dr. Carpenter states (although there are always elements of error through the unconscious assistance of other senses in cases of this kind) that Miss Bridgman recognized his brother, whom she had not met for a year, by the touch of the hand alone.

Every physician recognizes the fact of this difference of susceptibility to touch; and, in the diagnosis of certain conditions of disease, much depends on the *tactus eruditus*. I am not sure whether this delicacy of perception, by which muscle-reading is accomplished, is the ordinary sense of touch, that of contact, or of some of the special modifications of this sense. It is to physiologists and students of diseases of the nervous system a well-known fact that there are several varieties of sensibility—to touch, to temperature, to pressure or weight, and to pain—which, possibly, represent different rates or modes of vibration of the nerve-force.

The proportion of persons who can succeed in muscle-reading, by the methods here described, is likewise a natural subject of inquiry. Judging from the fact that, out of the comparatively few who have made any efforts in this direction, a large number have succeeded after very little practice, and some few, who have given the matter close attention, have acquired great proficiency, it is probable that the majority of people of either sex, between the ages of fifteen and fifty, could attain, if they chose to labor for it, under suitable

instruction, a certain grade of skill as muscle-readers, provided, of course, good subjects were experimented with. It is estimated that about one in five or ten persons can be put into the mesmeric trance by the ordinary processes; and, under extraordinary circumstances, while under great excitement, and by different causes, every one is liable to be thrown into certain stages or forms of trance; the capacity for the trance-state is not exceptional; it is not the peculiar property of a few individuals—it belongs to the human race; similarly with the capacity for muscle-reading. The age at which this delicacy of touch is most marked is an inquiry of interest; experience, up to date, would show that the very young or the very old are not good muscle-readers. I have never known of one under fifteen years of age to study this subject; although it is conceivable that bright children, younger than that age, might have sufficient power of attention to acquire the art, certainly if they had good instruction in it.

In these mind-reading experiments, as indeed in all similar or allied experiments with living human beings, there are six sources of error, all of which must be absolutely guarded against if the results are to have any precise and authoritative value in science.

1. The involuntary and unconscious action of brain and muscle, including trance, in which the subject becomes a pure automaton. I have used the phrase "involuntary life" to cover all these phenomena of the system that appear independently of the will. The majority of those who studied the subject of mind-reading—even physicians and physiologists—failed through want of a proper understanding or appreciation of this side of physiology.

2. Chance and coincidences. Neglect of this source of error was the main cause of the unfortunate results of the wire and chain experiments with mind-readers.

3. Intentional deception on the part of the subject.

4. Unintentional deception on the part of the subject.

5. Collusion of confederates. To guard against all the above sources of error it is necessary for the experimenter himself to use deception.

6. Unintentional assistance of audience or by-standers.

When the muscle-reader performs before an enthusiastic audience, he is likely to be loudly applauded after each success; and, if the excitement be great, the applause, with shuffling and rustling, may begin before he reaches the right locality, while he is approaching it; when, on the other hand, he is far away from the locality, the audience will inform him by ominous silence. The performance thus becomes like the hide-and-seek games of children, where they cry "Warm!" as the blindfolded operator approaches the hidden object; "Hot!" as he comes close to it; and "Cold!" when he wanders far from it. Some of the apparent successes with the wire-test may be thus explained.

In regard to all the public exhibitions of muscle-readers, it should

be considered that the excitement and *eclat* of the occasion contribute not a little to the success of the operator; the subjects grow enthusiastic—are partly entranced, it may be—become partners in the cause of the performer—and unconsciously aid him far more than they would do in a similar entertainment that was purely private. In a private entertainment of muscle-reading at which I was present, one of the subjects, while standing still, with his hands on the operator, actually took a step forward toward the locality on which his mind was concentrated, thus illustrating in a visible manner the process by which muscle-reading is made possible.

The subject under discussion, it will be observed, is to be studied both inductively and deductively. The general claim of mind or thought reading is disproved not by any such experiments as are here detailed, no matter how accurate or numerous they may be, but by reasoning deductively from the broad principle of physiology, that no human being has or can have any qualities different in *kind* from those that belong to the race in general. The advantage which one human being has over another—not excepting the greatest geniuses and the greatest monsters—is, and must be, of degree only. Mind-reading, in the usual meaning of the term, is a faculty that in any degree does not belong—indeed, it is never claimed that it belongs—to the human race; it cannot, therefore, belong to any individual. For one person to read the thoughts of another would be as much a violation or apparent violation of the laws of Nature as the demonstration of perpetual motion, the turning of iron into gold, or the rising of the sun in the west. Experiments such as here recorded, if made for the purpose of ascertaining whether certain persons have the power of reading thoughts, would be more than unnecessary; they would be exceedingly unscientific. Reasoning deductively also from the known laws of the involuntary life, the power to read muscles, in the method here described, is not only possible and probable, but inevitable. Everybody is a muscle-reader, although all are not capable of attaining the highest degrees of skill in the art.[1]

The one fact, the only fact brought out by these experiments that could not be predicted from known laws of physiology, is the exceeding refinement to which muscle-reading can be carried, the minuteness of the localities that are found, and the rapidity with which, oftentimes, the results are obtained. This fact is of permanent value to science, a new and positive addition to the physiology of the involuntary life, and of vast suggestion in relation to the general subject of the interactions of mind and body in health and in disease.

An incidental fact impressed on my mind during these researches

[1] Every horse that is good for anything is a muscle-reader; he reads the mind of his driver through the pressure on the bit, and by detecting tension and relaxation knows when to go ahead, when to stop, and when and which way to turn, though not a word of command is uttered.

was the prevalence and the power of the belief in animal magnetism. This delusion may well be regarded as the witchcraft of the nineteenth century; its hand is everywhere—on the press and the pulpit, on all our literature, on science itself, even on physiology, to which its phenomena rightly belong, and by which they can be and are fully explained. It is a tyrant that rules over the whole realm of the seemingly mysterious; the success of the orator on the platform, and of the physician at the bedside, is attributed to its aid, as of old superior learning and skill were attributed to the occult forces of magic. It may be doubted whether any other false belief of our time has had a more serious influence in retarding the progress of right reasoning than this, since it blocks the doors of investigation and prejudges the case when investigations are made, stimulates the too common habit of making the emotions do the work of the intellect, and becomes a sort of foster-mother to other and allied delusions.

It was the universality of this belief in animal magnetism that made mind-reading popular, since it furnished a basis as broad as the wildest theorizer could wish, on which could be erected a limitless variety of hypotheses; and many who rejected intuitively the claim of direct supernatural aid were made happy by the equally false and untenable claim of literal conveyance of thought from subject to operator through the agency of a supposed magnetic fluid.

COMPRESSED-AIR LOCOMOTIVE IN ST. GOTHARD TUNNEL.[1]

By C. M. GARIEL.

THE boring of a tunnel of any importance presents difficulties of various kinds, among which may be mentioned the clearing away of the rubbish arising from the excavation of the gallery, whenever that reaches any considerable length, and the work is carried on with activity. Such were the conditions under which the boring of the Mont Cenis Tunnel was carried on, and M. Fabre, the able contractor, has met with similar difficulties in the boring of the St. Gothard Tunnel, now being carried out.

The work was begun from two points, Airolo and Gœschenen, the two extremities of the future tunnel. The advance of the gallery, which is pushed on with activity, produces about 400 cubic metres of rubbish a day at each of the two faces of attack. To carry away this mass of rubbish, which is thrown regularly into trucks running on rails, it is impossible to employ locomotives, as the *cul-de-sac* nature

[1] Translated from *La Nature*.

of the galleries prevents effectual ventilation. The high price of horses and the large number required prevent their use. The idea suggested itself of making use for St. Gothard of machines moved by compressed air, which would have many advantages. First, it is well known that compressed air is used to work the perforating machines used in boring the tunnel; then, by the employment of compressed-air locomotives, ventilation of the galleries would be produced, as these machines would allow only pure air to escape; and then these motors would be more powerful than horses, and effect more rapidly the clearing away of the *débris*.

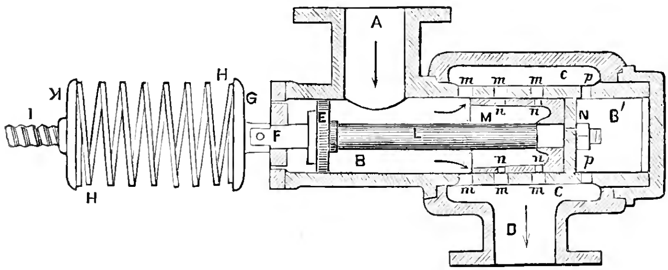


Fig. 1.

A first attempt was made in which two ordinary locomotives were employed, one at each side of the tunnel; the boilers, in which, of course, there was no water, were filled with condensed air under a pressure of four atmospheres. This air played the part usually done by steam, passed into slide-valves, entered the cylinders alternately on each face of the pistons, which it set in motion, and then escaped into the atmosphere.

It is easily seen that, if compressed air were to be employed, it would be indispensable to have a very considerable quantity of it; the boiler of a locomotive, sufficient when it is worked by means of steam constantly produced under the action of heat, was too small to contain a quantity of air sufficient for use without being filled. This led to adding to each locomotive a special reservoir for compressed air; each locomotive was accompanied, as a kind of tender, by a long sheet-iron cylinder, eight metres long and one and a half metre diameter, supported toward its extremities by two trucks, which, on starting, were filled with condensed air, and which communicated by a tube with the distributing apparatus of the cylinders. The locomotive then worked as before, except that compressed air came from the reservoirs instead of from the boiler. The two locomotives, the Reuss and the Tessin, worked economically for about two years, in spite of the awkwardness of the long cylinders that accompanied them. We can give some interesting figures resulting from the mean of a certain number of observations. At departure the pressure in

the reservoir was about seven kilogrammes per square centimetre; the locomotive having drawn a train of twelve loaded wagons along a course of about 600 metres, the pressure was found to fall to four and a half kilogrammes; the train then returned empty to the point of departure, and the final pressure was found to be two and a half kilogrammes.

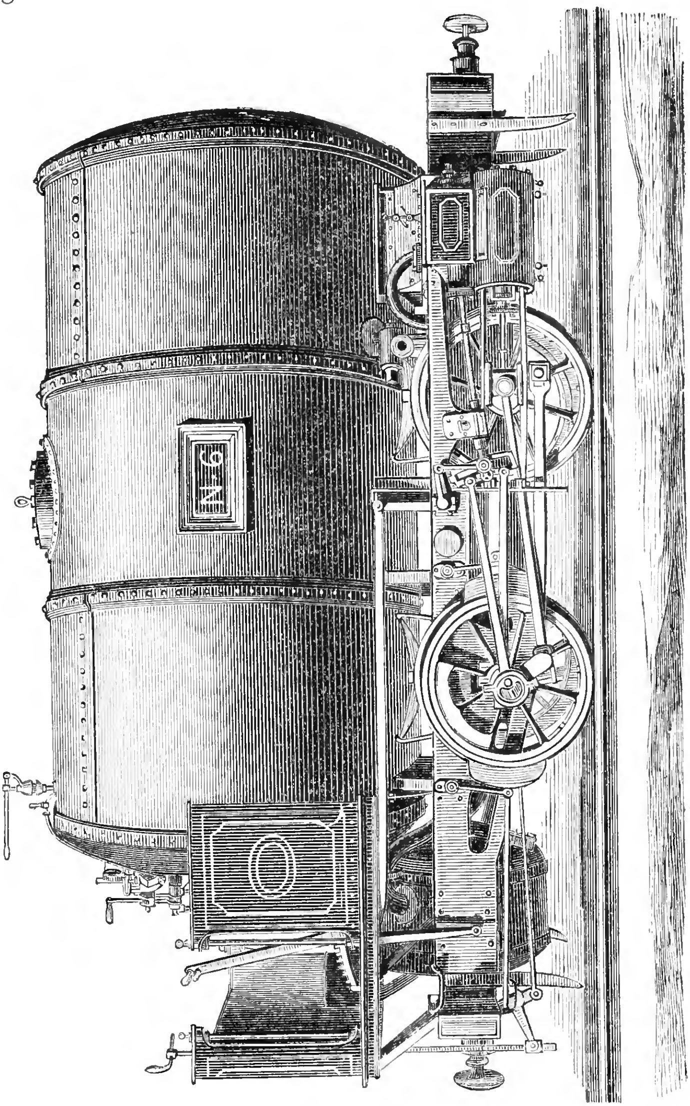


FIG. 2.—COMPRESSED-AIR LOCOMOTIVE USED AT THE ST. GOTHARD TUNNEL WORKS.

In spite of the relatively advantageous results which were obtained, the employment of compressed air in a steam-locomotive presented a certain number of drawbacks. It is expedient that the air

should issue from the cylinder under the least possible pressure, in order that refrigeration may be reduced to a minimum; for it is known that the expansion of gas is accompanied by a loss of heat which increases with the pressure. This condition was satisfied by causing the air to act under restraint; that is, by allowing the compressed air coming from the reservoir to enter during only a part of the course of the piston. But the admission of the air ought to vary if it is desired to obtain the same final effect, since the pressure in the reservoir diminishes continuously; and as the apparatus which regulates the admission was arranged to correspond only to determined fractions, but not to vary in a continuous manner, it followed that there was a greater expenditure of air than was necessary, and consequently a diminution in the length of the course over which the locomotive could run.

On the other hand, it is necessary that the air should arrive in the distributing apparatus with the least possible pressure, for it is in this apparatus, in the slide-valve, that the greatest losses take place, and these losses increase in proportion to the pressure. No means could, however, be thought of for diminishing the pressure in the reservoirs, which would have reduced considerably the work which the machines were capable of doing, unless by augmenting considerably the volume of the reservoirs, the dimensions of which were already unusually large.

At this stage M. Ribourt, the engineer of the tunnel, devised an arrangement which allows the compressed gas to flow at a fixed pressure, whatever may be the pressure in the reservoir. The gas in escaping from the reservoir enters a cylinder *B* (Fig. 1), over a certain extent of the walls of which are openings *m m*, that communicate with another cylinder *C*, which surrounds it to the same extent, and which is connected with the slide-valve by which the air is distributed, or, more generally, with the space in which this air is to be utilized. On one side moves a piston *E*, which shuts the cylinder and hinders the escape of the air. This piston carries externally a shaft *F*, which supports externally a spiral spring *H*, the force of which is regulated by means of a screw. Internally it is connected by another shaft *L* with a second piston *N*, which bears a cylinder *M*, movable in the interior of the principal pump, and forming thus a sort of internal sheath. This sheath presents openings *n n*, which may coincide exactly with those already referred to, and in that case the gas passes without difficulty from the reservoir at the point where it is to be employed. But if the sheath is displaced, the openings no longer correspond, there is resistance to the passage, and consequently diminution of the quantity of gas which flows out, and hence lowering of pressure in the exterior cylinder. By making the position of the sheath to vary continuously we may make the pressure of exit constant, notwithstanding the continuous variation at entry. But the

apparatus is automatic. In fact the part of the cylinder D comprised between the b[illegible]m and the piston N communicates by openings p (which are ne[illegible] covered with the escape-tube of the gas), in such a manner that [illegible]pon its posterior face the piston N receives the pressure of the gas at the moment when it flows, a pressure which it is sought to render con[illegible]tant. The piston E receives on its anterior face the action of the spring which can be regulated at pleasure. As to the other faces of the two pistons, they are subjected to equal actions proceeding from the pressure of the gas at its entry, actions which thus cou[illegible]ract each other; so that the forces which determine the position o[illegible] movable system are, on the one hand, the tension of the spring, a [illegible]stant and determined force, and, on the other hand, the pressure o[illegible] flowing gas; and thus equilibrium cannot occur unless the two forces are equal. If the gas should flow in too great a quantity, the pressure increases on the posterior face of the piston N, the spring is overcome, and the movable system advances a little toward the left; but then the orifices are partly covered and the flow diminishes. If the pressure then becomes too weak at the exit, the spring in its turn prevails, pushes the sheath toward the right, uncovers the orifices, and consequently a greater quantity of air may enter.

The machines which are now used at the St. Gothard Tunnel, genuine comp[illegible]ssed-air locomotives, are furnished with M. Ribourt's apparatus. They consist of the following parts: A sheet-iron reservoir to contai[illegible] the compressed air is mounted on a framework quite like that of s[illegible] locomotives, and carrying glasses, cylinders, distributing appa[illegible], etc. The tube for receiving the air possesses, within reach of t[illegible]e driver, the automatic valve of M. Ribourt. The screw being ea[illegible]gulated, the air can with certainty be made to issue from the [illegible]atus at a determined pressure. This air then passes into a sm[illegible]ervoir (about one-third metre cube), intended to deaden the shoc[illegible]h are always produced when the machine is set agoing or stopp[illegible]stly, this small reservoir communicates with the cylinders, an[illegible]r which reaches them acts in the same manner as steam in ordina[illegible]omotives.

The p[illegible]e in the principal reservoir at the point of exit depends on the p[illegible]f the compressing apparatus; at St. Gothard it may attain fo[illegible]teen kilogrammes per square centimetre, but is ordinarily about 7.[illegible] kilogrammes. The pressure in the small reservoir is arbitrary, depending on the regulation of the screw; at St. Gothard it has a mean of 4.20 kilogrammes. The entire machine weighs about seven tons.—*Nature.*

GAS MANUFACTURE AND GAS COMPANIES.[1]

CONDENSED FROM THE BOSTON REPORT,

BY WILLIAM E. SIMMONS.

THERE are three kinds of gas, named after the substances from which they are obtained, as coal, petroleum (or naphtha), and water gas. The first two are produced by destructive distillation of coal and petroleum, or naphtha, the last by passing a current of steam over a bed of incandescent anthracite. Coal-gas is the kind in general use, petroleum or naphtha gas being used chiefly as an enricher; and water-gas, used in only a few places and for a comparatively short time, is as yet on its trial. The general principles involved in the manufacture of each kind of gas will first be noticed; then the relative merits of the products will be considered in regard to quality, cost of manufacture, and respective peculiarities; and, finally, a comparative view will be taken of several leading companies; after which the relationship of gas companies to municipalities, and the subject of competition, will be examined.

When coal is subjected to high heat in a closed vessel, certain gases and vapors are evolved, some of which are combustible, and some, like steam, condensible, a residue of charcoal or coke being left behind. This process is termed destructive distillation, and the property displayed by coal is common to all vegetable and animal substances; but only coal and petroleum have been used economically in the production of illuminating gas on an extensive scale. The distillation is the most important operation in the manufacture, but it is necessary to remove from the gas, before it is fit for burning, the condensible vapors, as tar, water, etc.; and those non-condensible gases, as carbonic anhydride (carbonic acid), which either largely diminish the illuminating power, or which give rise, in the burning of the gas, to injurious products of combustion, such as sulphuretted hydrogen and ammonia. The removing of these very materially affects the cost of production. The distillation is effected in iron or clay

[1] Abstract of a Report to the City of Boston, A. D. 1876, by the Gas Commissioners, Messrs. Charles F. Choate, John Felt Osgood, and Edward S. Wood, appointed in January, 1875, who were instructed "to investigate and report—1. On the quality and price of the gas furnished in Boston, as compared with that of other large cities in this country and Europe; 2. Whether any improvements can be made in the present methods of manufacturing gas by the different companies in this city; 3. Whether it would be expedient for the city to undertake the manufacture and supplying of gas for public and private lighting; and, 4. Whether any further legislation is desirable to enable gas-consumers, or the municipal authorities, to secure a prompt and impartial investigation of complaints against private companies, and an efficient remedy for any abuses of which they may be found guilty."

retorts, from three to seven of which, according to circumstances, are heated with one fire of coke to a cherry-red (1,478° to 1,830° Fahr.) for iron, or to an orange or white heat (2,000° to 2,300° Fahr.) for clay retorts; 160 to 260 pounds of coal constitute the charge for a single retort, and the distillation continues uninterruptedly for four to four and a half hours. The outer layers of the charge, being suddenly raised to a high temperature, evolve vapors which contain a large amount of carbon. These, in passing through the retort, are converted into fixed gases of a high illuminating power. The inner parts of the charge, undergoing distillation more slowly, give out vapors which, in passing through the highly-heated coke on the surface, are more completely decomposed than the first evolved, and are, therefore, of a lower illuminating power. It has been shown, for example, by Mr. C. D. Lamson, of the Boston Gas-Works, that the illuminating (or candle) power of the gas diminishes in a rapidly-increasing ratio with each half-hour of the distillation; and also that, after the third half-hour, the quantity of gas produced similarly decreases. The largest quantity, as well as the richest gas, is, therefore, obtained in the first part of the distillation. By *candle-power* is meant that the gas, burning at the rate of five cubic feet per hour, will give as much light as the stated number of standard sperm-candles burning at the rate of 120 grains per hour, or two grains per minute.

The gas passes next into the hydraulic main, where it is made to bubble up through a half-inch to an inch of water, and thus some of its vapors are condensed. It then goes to the condenser, a series of iron tubes surrounded by water, to be cooled and more completely rid of its tar and other vapors, which are precipitated and led away. Going to the washers, a series of chambers where it is brought in contact with jets of water, and to the scrubbers, where it passes through a collection of coke, fire-brick, etc., moistened with water, it is relieved of the rest of the tar and also of the ammonia.

The third step in the manufacture is purification, which removes from the gas the noxious elements, chiefly carbonic acid and sulphuretted hydrogen. The first lowers the illuminating power very greatly: one per cent. being sufficient, it is said, to diminish it five per cent. The sulphuretted hydrogen and other sulphurous compounds give rise in burning to sulphurous and sulphuric acids which may injure, by their corrosive action, delicate structures, such as books, gilding, silks, etc., that are exposed to the air of the room in which the gas is burned. Lime and oxide of iron are used in various methods to purify the gas. Lime is used both wet and dry. In the wet-lime process the gas is passed through the milk of lime, which, uniting with the carbonic acid to form a chalk, effectually removes it, and takes away most of the sulphur compounds too, by uniting with them to form calcic sulphide or calcic sulpho-carbonate.

The use of this process has generally been abandoned, however,

on account of the foul odor evolved from the lime when it is taken from the purifier. The dry-lime process consists in passing the gas through moistened slacked lime placed upon trays. This is about as effective as the other, and has generally superseded it. The iron process consists in passing the gas through some form of the hydrated sesquioxide of iron mixed with other substances. The great advantage of this process is its economy, it being practicable to use the same mixtures over and over almost indefinitely. The New York Mutual Company, for instance, have used one mixture satisfactorily for three years.

Either petroleum or some of the products of its distillation at a low temperature, as naphtha, rhigolene, gasolene, etc., may be used in the manufacture of gas. These products are of little commercial value as compared with those, like kerosene, which are produced at a higher temperature, but for this reason they are of especial value for the manufacture of gas. The principles on which the manufacture of petroleum-gas depends do not differ much from those involved in the making of coal-gas. In both cases, as already stated, the material is subjected to destructive distillation in a retort; but in this the material may either be introduced directly into the retort, or first converted into a vapor, and conducted into it in that state. The first step, however, is to vaporize the liquid either in the retort or before it reaches there; and the second, to decompose the vapor, and convert it into a fixed gas, which is carried into an hydraulic main and condenser in the same way as coal-gas. One great advantage of the naphtha-gas is that, containing neither sulphur compounds nor ammonia, it needs no purification, and therefore saves one item in the expense of manufacture. Moreover, a loss of some of the luminiferous hydrocarbons is avoided, a certain amount of them being necessarily condensed in the passage through the washers, scrubbers, and purifiers.

The manufacture of water-gas differs entirely from that of coal or naphtha gas. It involves the production, first, of a non-illuminating gas from steam, and, second, of petroleum, naphtha, or cannel gas, to furnish the illuminating power. The great advantage of it is, that very large volumes of non-luminous combustible gas can be made very cheaply. This is done by passing steam over incandescent carbon, which, having a very powerful attraction for oxygen, abstracts it from the steam (water being a compound of hydrogen and oxygen), and unites with it, forming, at first, carbonic acid. This, in passing over another bed of coal, is deprived in turn of one-half its oxygen, and converted into carbonic oxide. Hydrogen, the other constituent of the steam, being set free, mixes with the carbonic oxide. The resultant is a mixture of hydrogen and carbonic oxide, which gases are both combustible but non-illuminating. In some processes for the manufacture of this gas, the petroleum or naphtha gas

is not mixed with the water-gas until the latter has been purified; in others the petroleum is added directly to the coal. Anthracite coal, only, is used in the manufacture of water-gas, and great care is necessary to keep the temperature up to a white heat, since, if it falls too low, a large proportion of carbonic acid will be formed, and will injure the illuminating power of the gas unless it is removed by purification. Anthracite coal contains sulphur, and yields ammonia when distilled, so that purification is as necessary for water as for coal-gas, and therefore no saving is made in this respect. The real saving is in coal, since a large volume of steam can be decomposed by one ton.

It is necessary now to make a more particular inquiry into the nature of the different gases and compare them with each other. Coal-gas in its salable condition is composed about as follows:

NAMES.	Heidelberg.	Bonn.	Chemnitz.	London, Common.	London, Cannel.
Hydrogen	44.00	39.80	51.29	46.00	27.70
Marsh-gas	38.00	43.12	36.45	39.50	50.00
Carbonic oxide	5.73	4.66	4.45	7.50	6.80
Olefiant and other hydrocarbons	7.27	4.75	4.91	3.80	13.00
Nitrogen	4.23	4.65	1.41	0.50	0.40
Oxygen	....	....	0.41	....	....
Carbonic anhydride	0.37	3.02	1.08	0.70	0.10
Steam	....	....	....	2.00	2.00

The hydrogen and carbonic oxide burn with a non-luminous flame, and marsh-gas burns with only a slightly-luminous one, the illuminating power coming almost entirely from the olefiant gas and other hydrocarbons. The oxygen, carbonic acid, and nitrogen, being incombustible, injure the illuminating power very greatly. The oxygen and nitrogen are admitted accidentally by the introduction of a little air in charging the retorts. Hence, other things being equal, the illuminating power of the gas increases with the proportion of olefiant and other hydrocarbons, and these depend chiefly on the kind of coal used and the temperature at which it is carbonized. The gas-coals are the bituminous caking coals and cannel. The bituminous shales, like the boghead mineral of Scotland, and asphalt minerals, like the Albertite of Nova Scotia and the Grahamite of West Virginia, are used in small quantities for enriching. The yield of good gas-coal, like the Penn, is about 10,000 cubic feet of 15 to 16 candle-power gas to the ton (2,240 lbs.). The enriching coals yield a larger amount of richer gas, and the asphalt minerals from 13,000 to 15,000 cubic feet of 30 to 50 candle-power. The relative cost of enriching with these or with naphtha is a very important question. In a number of experiments made at the Boston Gaslight Works, for the purpose of testing the value of Albertite as an enricher, it was found that the

yield varied from 13,440 to 16,016 cubic feet of 36.08 to 54.45 candle-power gas per ton (6 to 7.15 feet per pound). Experiments on cannel of different kinds have given various yields, from 3.8 feet of 20.52 candle-power gas per pound to 4.74 feet of 30.40 candle-power.

The principal impurities in coal-gas are, as already indicated, sulphuretted hydrogen and other gases containing sulphur and ammonia. The presence of a small amount of these cannot be avoided, and is not injurious, since the sum of the products of the combustion of these substances, formed by the burning of the gas from a single burner during an entire evening, is very small. In fact, the presence of a slight amount of ammonia is beneficial, in tending to neutralize the sulphurous and sulphuric acids formed by that portion of the sulphur which cannot be renewed. The limit prescribed by law for the London companies is 20 grains of sulphur and 2½ grains of ammonia per 100 cubic feet. The specific gravity of illuminating gas is an important quality, since it increases in a nearly constant ratio with the candle-power, so that, knowing the one, the other can be told pretty nearly, and *vice versa*. It varies usually from 0.400 to 0.500; the specific gravity of air, 1.000, being taken for the unit. The denser the gas the more slowly it will pass through a given orifice, and so on this quality depends in great measure the quantity which passes through the consumer's meter and burner.

In regard to petroleum as a gas-making material experiments made by Prof. A. Wagner show that naphtha is better and more economical than it or any of the heavy oils. Fifty kilogrammes of petroleum produced 1,547 cubic feet of gas, while the same amount of naphtha produced 1,619 cubic feet. Both petroleum and naphtha produce a large amount of acetylene, a gas which contains a large proportion of carbon. In the experiments referred to, five per cent. of acetylene was evolved, 35.96 per cent. of other heavy (rich) hydrocarbons, and 59 per cent. of light (poor) hydrocarbon gas; the petroleum being split up, with deposition of carbon, into a mixture of acetylene, heavy and light hydrocarbon gas, and hydrogen. In this country, where petroleum and its products are much cheaper than they are in Europe, it has been found that on a large scale 60 to 80 cubic feet of 50 to 70 candle-power gas can be made from one gallon. In a series of thirteen experiments on crude petroleum made by Mr. C. D. Lamson, of the Boston Gaslight Company, the average yield per gallon was 72.71 cubic feet, and the average of six tests of candle-power was 45.73. In seven experiments on naphtha the average yield was 79 cubic feet, candle-power 53.48. This is equivalent to a yield per barrel respectively of 3,053.82 and 3,338.58 cubic feet. According to Mr. J. D. Patton, about 70 cubic feet of 80 candle gas, or 80 feet of 70 candle gas to the gallon, is the maximum yield of petroleum or naphtha. A much smaller burner than the ordinary must be used for gas obtained from pure Albertite, petroleum, or naphtha; otherwise the flame will smoke,

and much light be lost, although, on account of their greater specific gravity, less of any of such gases would pass through the same burner in a given time.

Reference has been made to the large quantity of water-gas that is made by one ton of coal. In one of the processes employed, the average result of four months' working was 1,000 cubic feet of gas to 67.71 pounds of coal and 3.22 gallons of crude petroleum, or 33,082 cubic feet of about 19 candle gas to one ton of coal and 106.5 gallons petroleum: allowing 70 cubic feet for each gallon of petroleum, or 7,335 feet for the whole, there remains 25,745 feet for the one ton of coal. It will be remembered that the amount of gas obtained by distillation, from the very best coal, ranged between 10,000 and 16,000 cubic feet. Water-gas contains as a rule 40 to 50 per cent. of hydrogen, 30 to 40 per cent. of carbonic oxide, 10 per cent. of naphtha or petroleum gas, and a few per cent. of carbonic acid. The large proportion of heavy petroleum-gas (sp. gr. 0.600 to 0.700) and carbonic oxide (sp. gr. 0.967) makes its specific gravity much heavier than that of coal-gas; but the hydrogen, which is the lightest known gas (sp. gr. 0.067), brings it down to between 0.500 and 0.600.

It has been seen that the gas of common coal is of comparatively poor illuminating power, unless enriched by the gas of other coals or of petroleum, and that water-gas of itself possesses no illuminating power whatever. Although, in considering the nature of the different gases, their relative values were incidentally compared, it is necessary to speak of them now more particularly. In regard to quality, it has been shown that naphtha-gas is the purest, since it contains no sulphur or ammonia, and that it is the richest, being from 60 to 80 candle-power, while common coal-gas is only from 15 to 20 candle-power. It is also the most economical, alike for producer and consumer: for the consumer, because, owing to its higher specific gravity, it burns much more slowly than the coal-gas, while it also gives a better light. The higher the specific gravity of the gas, the longer it will take to pass through a given orifice, and therefore the more slowly it will consume; and the higher the candle-power, the less gas is burned in giving the same amount of light. It is more economical for the producer, because, in the first place, there is a great saving in its manufacture, in the handling of the material. The retorts can be supplied continuously, and the frequent interruptions for recharging necessary, in the use of coal, are avoided. Each retort, too, can be made to produce a much larger amount of gas in the one case than in the other. About 10,000 feet of petroleum-gas can be made daily with a single retort, against about 5,000 feet of coal-gas; and 60,000 to 70,000 cubic feet per day, per stoker, against 25,000 to 30,000. Hence there is a saving both of labor and wear and tear of works. The cost of works for making pure petroleum-gas is also much less than that of coal-gas works. Notwithstanding these facts, the commissioners, whose report we have

been considering, did not deem it practicable to change at once to the use of pure petroleum or naphtha gas in Boston, as the burners in use are, for reasons already given, not suitable; the works employed to produce coal-gas are not adapted to this, and as the flame of petroleum-gas "burning in an appropriate burner is a very small flame," it would not in their opinion prove satisfactory to consumers, although the amount of light would be the same if not greater. The objection that petroleum-gas in any form injures the metres was found to be without warrant.

The practice which obtains with the Detroit Mutual Company and others, of adding air to naphtha-gas to reduce its illuminating power so that it can be burned in an ordinary burner, was judged by the commissioners to be the reverse of economical, to both the company and consumer, because the deterioration of the gas by this means is in greater ratio than the increase of its volume. It is said that one per cent. of air will reduce the illuminating power six per cent., or more than carbonic acid, the removal of which is considered necessary by all gas-engineers for the sake of economy. It was for this reason that the first attempt to make illuminating gas from petroleum (that at Saratoga by the Gale and Rand process) failed.

What is true of the value of naphtha as a gas-making material used alone, is also true of its value as an enricher. Experiments already here referred to, although not expressed in terms of equality, imply the superiority of naphtha to Albertite, which is about the best of the enriching coals. The yield from a ton of the latter, which costs about $25, was, on the average of a number of experiments made by the Boston Gaslight Company, only 14,694.4 cubic feet of 55 candle gas; while the yield of $25 worth of naphtha (valuing it at ten cents a gallon, which is rather high) would be 19,872.5 cubic feet of 64.5 candle gas, or 5,178.1 cubic feet more gas of richer quality than a ton of Albertite. By the use of naphtha, too, a larger amount of gas is obtained from the ordinary caking coal. In enriching with Albertite the coal with which it is mixed is distilled in an iron retort at a comparatively low temperature; while, if naphtha be used, all of the common coal can be carbonized in a clay retort, which is acknowledged by all to be more economical, and all of the gas in the coal can be exhausted, so that about 1,000 cubic feet more can be obtained per ton. The iron retorts are more expensive than the clay, because their first cost is greater, and they do not last as long. In making gas on a large scale, about one-half the number of retorts can be dispensed with, in the use of naphtha as an enricher. The New York Mutual Gas Company, for example, in this way, make as much gas with forty retorts as can be made in the other with eighty; and with the disuse of the extra forty retorts the labor necessary to tend them is dispensed with. The increased yield of the coal by the use of naphtha, referred to just now, is demonstrated by practical experience to be

very considerable. Comparison of the result of a year's work obtained by the New York Mutual Company, which uses naphtha for an enricher, and the Boston Gaslight Company, which uses Albertite, shows that the former obtained 10,975 cubic feet of 19 to 20 candle-power gas per ton of coal used, while the latter obtained only 8,779 cubic feet of 18 to 19 candle gas, a difference of 2,196 cubic feet per ton in favor of the naphtha.

In regard to the alleged danger in keeping large quantities of naphtha in store, the commissioners say: "There is no doubt that it is more difficult to extinguish burning naphtha than burning coal; but the statements that naphtha is like gunpowder (explosive), and dangerous to store, are erroneous. In fact, it is almost impossible to mix naphtha-vapor and air so as to make an explosive mixture, for the reason that, when the proper amount of oxygen is present, the mixture is diluted with so large a bulk of inert nitrogen that it cannot be ignited." In regard to the supply, they see no reason to fear that it will be inadequate to "any demand which may exist in the future." The oil-region extends over a wide expanse of country, embracing large districts in Pennsylvania, Eastern Ohio, West Virginia, Kentucky, Indiana, and Western Canada. The production in 1874 was 10,910,303 barrels—larger than ever before by more than 1,000,000 barrels; the average price was 2.8 cents per gallon, or $1.17 per barrel.

The objections urged against water-gas are, that its specific gravity is too high; that it contains a large proportion of the extremely poisonous gas, carbonic oxide; and that the manufacture, being in its infancy, is not yet proved to be a success. The first is of no importance, since the specific gravity, unless it is caused by the presence of a large amount of carbonic anhydride, is high in almost exact proportion as the illumination power is great.

The commissioners say of the second objection that it is, in their opinion, "sufficient to entirely prevent the use of the mixed hydrogen and carbonic oxide" (unenriched water-gas) "alone for heating purposes, for the reason that, since it is devoid of odor, its escape from pipes and diffusion through the air of an inhabited room, in dangerous amount, could not be detected. The addition to it of petroleum-gas as an enricher, for illuminating purposes, at once imparts to it a peculiar odor, as strong as that of coal-gas, which would lead to the immediate detection of a leak." Carbonic oxide is one of the most active poisons, producing, when inhaled, speedy death. Unlike carbonic acid, which, when it poisons, does so by merely preventing the entrance of air or oxygen into the lungs, as water does in case of drowning, so that persons affected can be readily resuscitated, it is a true physiological poison. And while the first can be rendered harmless by a moderate dilution with atmospheric air, the last produces death almost as readily when diluted as when pure. It forms a com-

pound with the red coloring-matter of the blood, which is more stable than that formed by carbonic anhydride, and cannot be readily decomposed by oxygen. According to Leblanc, one volume of it diffused through one hundred volumes of air totally unfits it to sustain life; and it appears that the lamentable accidents which too frequently occur from burning charcoal or coke, in braziers and chafing-dishes, in close rooms, result from the poisonous effects of the small amount of carbonic oxide which is produced and escapes combustion, since the quantity of carbonic anhydride thus diffused through the air is not sufficient in many cases to account for the fatal result. The commissioners, therefore, do not consider the use of water-gas as safe as that of coal or naphtha gas, but they say that the addition to it of petroleum-gas greatly diminishes the danger. So far as they are aware, no accidents have occurred from its use in this country, although there have been several in Europe. The third objection, that the manufacture of water-gas is yet in its infancy, is to a certain extent true, as, although it has been in use in Utica, New York, where the works were recently burned, and is in use in one or two small places, as Poughkeepsie, New York, and the Manayunk District of Philadelphia, it has not been adopted by any of the large companies of Europe or America.

By a comparison of the results obtained by the leading companies in this country and Europe, some interesting facts are shown concerning the cost of production, which, in the United States, has been shrouded until now in mystery—the value of the different processes, the prices charged, etc. The accounts of the London companies, and of the companies of several other large European cities, are published, and therefore open to examination; but, with one or two exceptions, notably of the Philadelphia works, which are controlled by the city, this is not the case with American companies, which are, on the contrary, careful in guarding the secrets of their business. From most of them, certain items of information could be obtained by the commissioners only under the promise of secrecy. The prices charged consumers in Europe are generally much lower than those charged in this country, and it seems that, owing to cheaper labor and better prices obtained for the residuals (coke, tar, and ammoniacal liquor), the cost of manufacture is considerably less. The average price varies with companies and places, from $0.827 per 1,000 cubic feet at London to $1.51 at Paris. The lower price given, however, is charged by only one London company, the S. Metropolitan; the prices of the other companies are much higher, varying from $1.09 to $1.367. The lowest cost of production, 59 cents per 1,000 feet, is reached by the London company just named, and the highest, $1.21, by the Hamburg company. The high cost in Hamburg is to be partly accounted for by the fact that the price of labor is higher there than in any other European city. In 1875 the lowest price in any of the large cities

of this country was in Philadelphia—$2.30. In Boston the price was $2.50, and in New York $2.75; these prices were, however, reduced, in the early part of 1876, to $2.25 and $2.50, respectively. The prices charged in the smaller cities are, as a rule, much higher, being in some cases—Ashland and Bloomsburg, Pennsylvania, for example—as high as $10 per 1,000. In Detroit, Michigan, owing to a temporary war between an old and a new company, the price was as low as 50 cents per 1,000 in one part of the city, and $1 in another; while in a third, supplied only by the pipes of the old company, it was $3.

With regard to the Philadelphia company, which, as before stated, is under control of the municipal authorities, it was found that, while the price charged was the lowest, the cost of the gas was the highest. It had been alleged that the authorities were in the habit of giving employment to laborers for political purposes about election-time, and it was found that the cost of labor was ten cents per 1,000 feet greater than in other works. The proportion of capital to business done varies very greatly with different companies. In Washington, D. C., it was $1.46 per 1,000 cubic feet of gas sold, and in Brookline, Massachusetts, $17.50. "This," remark the commissioners, "must be due, to a great extent, to improper investments or expenditures, and is the great argument against any monopoly being in the hands of a private corporation, and in favor of its management by municipal authorities, since a corporation, having a monopoly, has the power to charge such a price as may be necessary to pay its dividends, and has, therefore, no inducement to diminish its capital, but, on the contrary, one to increase it." The average capital and borrowed money of the London companies, in 1874, was $4.54 per 1,000 cubic feet of gas sold.

As information given them touching the net cost of manufacture was confidential, the commissioners were deterred from publishing the facts as they found them, and forced to resort to giving an approximation. For this purpose, they compare the New York Mutual Company and the Boston Gaslight Company, as being more nearly on an equality, with respect to business done and capital employed, than any others, and deduct the "amount of dividends and taxes *pro rata* per 1,000 cubic feet sold from the average price of gas to the consumer." Each of these companies has an actual paid-in capital of $2,500,000, and bonds to the amount of $500,000. The first paid, in 1875, twenty per cent. dividends on the capital, six per cent. interest on the bonds, and $50,000 taxes, making, in all, $580,000, which, divided among 509,000,000 cubic feet of gas sold, gives $1.14 for each 1,000 feet; this amount, deducted from the net price per 1,000 feet, $2.65, leaves $1.51, which is supposed to be the cost of the gas; and that, the commissioners assure us, is even more than the actual cost. In the same manner the cost of the Boston gas is ascertained to be $1.85 per 1,000 feet, or thirty-four cents more. This difference is

partly due to the use of Albertite instead of naphtha as an enricher, which, as already shown, is more expensive, and partly to greater cost of common coal, labor, and distribution, and smaller receipts for residuals. The leakage, for instance, is only seven per cent. with the New York Mutual, while it is eight and one-half per cent. with the Boston company. The commissioners, however, believe that the gas of this company ought not to cost the consumers more than $2 or $2.10 per 1,000 cubic feet.

Examination of the gas of the New York Mutual showed it to be very pure, and of a high illuminating power. It contained of ammonia about one-quarter of a grain in 100 cubic feet, and less than nine grains of sulphur. Its specific gravity averaged 0.729, and its illuminating power between 20 and 21 candles. The London companies, as before stated, are prohibited by law from allowing the amount of ammonia in each 100 feet to exceed two and one-half grains, and of sulphur twenty grains, and from permitting the candle-power to fall below 16. The amount of ammonia in the Philadelphia gas was found to be 52 grains per 100 cubic feet. "The candle-power," say the commissioners, "is always within the control of the company, and it ought in no case to be allowed to fall below the London standard." In regard to the charges of smokiness made against the gas of the New York Mutual Company, the commissioners, after a thorough investigation, ascertained that where smoke occurred it was due to the ignorance or carelessness of consumers in using unsuitable burners.

All the principal water-gas works were visited, and found to be producing gas of good quality. The cost by the Harkness process, used at New London, Connecticut, exclusive of the cost of labor, purifying, and fuel for the petroleum-retort, which, by this process, requires a separate fire, was found to be about 75 cents per 1,200 feet. The Lowe process, in use in Utica until the works were burned, requires but one fire for decomposing both steam and petroleum, so that it possesses an advantage over the other in regard to the cost of production. The friends of this process claim that, manufacturing at the rate of 200,000 cubic feet per day, the gas can be made (coal being at seven dollars a ton, and petroleum at twelve and one-half cents a gallon) at a cost of 53 cents per 1,000 feet, exclusive of labor, fuel, and purifying. For the Gwynne-Harris process, in use at Poughkeepsie, New York, it is claimed that the cost, under like conditions, is only 37.3 cents per 1,000 feet.

The relation of a gas company to a municipality, the commissioners say, is a peculiar one in many respects, and the company ought not, therefore, to be viewed in the same light with other manufacturing corporations. It supplies a commodity which is not a luxury but a necessity; the sale of its product is a limited one, being confined to the city or district which it supplies; and it is expected to lay its

pipes so that all who desire to burn gas may do so, which entails an expenditure in distribution that is not, perhaps, repaid by the sale of gas in the particular locality for many years; and a very large part of its first investment is in material that would not give any return in case it became bankrupt, or desirous of withdrawing from the business. Therefore it is entitled to a great deal of consideration, provided it performs "its duty to its customers, and is honorable in all its transactions." A general view is then taken of the London companies, the result of their competition, and the efforts which have been made to control them by parliamentary enactments. In the efforts that were made from time to time, between 1820 and 1857, to reduce the price of gas, a number of new companies were chartered and established, until at length thirteen existed, and in some of the streets the mains of three or four companies lay almost in contact with each other. When a leak occurred it was impossible to tell from which main the gas escaped—it was, in some places, impossible to tell with certainty to what company a particular main belonged, and it sometimes happened that a consumer would use the gas of one company and pay for it to another. These circumstances, of course, did not tend to lessen the cost of gas, and so the companies finally agreed to district the city off and abandon competition. Then followed a consolidation of five companies with others, so that only eight remained, and latterly three of these consolidated into one, whereby the number is reduced to six—which result, corresponding as it does with the history of gas companies elsewhere, proves that competition does not operate to reduce the price of gas. It only illustrates the truth of the remark made by John Stuart Mill, and accepted by other political economists, that "where the competitors are so few (as in the case of gas companies), they always end by agreeing not to compete. They may run a race of cheapness to ruin a new candidate, but as soon as he has established his footing they come to terms with him." It eventually ends by the public having to pay the profits on two or more capitals instead of one.

As early as 1820 a committee of Parliament, of which Sir William Congreve was chairman, reported in favor of granting a monopoly under certain restrictions to each company in its own district; but the recommendation was not adopted. As the matter now stands the companies are restricted by law from charging more than 3*s*. 9*d*. per 1,000 cubic feet, and from paying more than ten per cent. dividends on stocks. The law also compels the companies to submit their accounts to the inspection of an auditor, at his pleasure; to publish annual statements of the cost of manufacture, profits, etc.; and it empowers the local municipal authorities to erect works and supply gas if the companies will not agree to sell gas for 3*s*. 9*d*.; and the same authorities may, if they think that ten per cent. dividends can be paid at a less price

than 3*s*. 9*d*., call for the appointment of three commissioners to reduce the price. And a company may call for a like commission to raise the price if 3*s*. 9*d*. will not pay its allotted dividend.

With regard to the manufacture of gas by municipalities, the commissioners say that the best argument in its favor is, that about fifty cents per 1,000 feet of the gas sold must be applied to the payment of dividends to stockholders, while "a much smaller amount than this, at the low rate at which money could be hired by the city, would be sufficient to pay interest on the capital, and at the same time allow a sufficient amount to be laid aside, in the form of a sinking-fund, to entirely liquidate the debt in a few years." However, "as a rule a city cannot manufacture gas as cheaply as a private corporation, since it is almost impossible to avoid the influence of politics on any city undertaking." Concerning the Philadelphia works, which is the most notable example of municipal manufacture in this country, the commissioners speak as follows: "Notwithstanding all the disadvantages arising from political influence in the management of these works, we find the profits for the year 1875 to have been $793,244.12; and after deducting for interest on the bonds, etc., the sum of $302,986.21 went toward the increase of the sinking-fund, which, on December 31, 1875, amounted to $2,470,193.93, while the whole amount of outstanding bonds is $5,400,000; thus leaving only $2,929,806.07 to be provided for, when the whole works, costing nearly $14,000,000, will become the unencumbered property of the city."

The conclusions arrived at by the committee may be summarized as follows: That although Boston is supplied with gas of excellent quality, at a lower price than most other cities of the United States, the same could be made much cheaper than it is, by the use of naphtha or petroleum as an enricher, but it is doubtful whether the appliances for using that substance could be employed by the Boston company without paying a considerable royalty, or becoming involved in lawsuits for alleged infringement of patents, which are, however, of doubtful validity; that the "Gwynne-Harris" and "Lowe" water-gas processes offer fair prospects of success, and should be carefully watched and studied; that the existing companies in Boston, and other cities in Massachusetts, should be granted monopolies in their several districts, subject, however, to the supervision of a permanent Board of State Commissioners, similar to the Railroad Commissioners, and to a full annual publication of their entire business, and be required to keep their gas at all times up to an illuminating power of sixteen candles, free from sulphuretted hydrogen, and from more than twenty grains of sulphur and five of ammonia, per 100 cubic feet; and, finally, that the authorities of the city of Boston should be empowered by the Legislature to erect works and manufacture and supply gas to the citizens in case any company which, by the terms of its charter, is not subject to legisla-

tive control, should refuse to comply with such reasonable suggestions as may be deemed necessary to insure publicity in regard to its business, proper inspection of its gas, and a limitation of its earnings.

SKETCH OF PROFESSOR J. P. COOKE, JR.

THE position occupied by this gentleman in American science is one of marked distinction as a successful original investigator, and also as an efficient reformer in the work of scientific education. He is known at home and abroad both by the extent and importance of his experimental researches, and by the high-toned and thorough-going character of his expository works on chemistry and physics. It is a fact of no little significance that, although Prof. Cooke had the advantage of a university training, he was self-taught in chemistry, as his collegiate culture afforded no special preparation for his chosen field of labor, while the impulse which started him in a scientific career came from popular lectures outside the university. Yet he has probably done more than any other man to give chemical science its proper status in the collegiate curriculum as a valuable disciplinary study entitled to a leading place in an effective system of liberal culture.

JOSIAH PARSONS COOKE, Jr., was born in Boston, October 12, 1827, and is a descendant of Major Aaron Cooke, who emigrated from England in 1630, and became one of the first settlers of Dorchester, and afterward of Northampton, Massachusetts. His father, a lawyer, is still living, at the advanced age of ninety, the oldest member of the Suffolk Bar.

Young Cooke received his early education at the Boston Latin School, and entered Harvard College in 1844, where he graduated in 1848. After passing a year in Europe for the recovery of his health, he returned to the university in 1849, as Tutor in Mathematics. He was soon afterward appointed Instructor in Chemistry, and at the close of the following year he succeeded to the Erving Professorship of Chemistry and Mineralogy, which he has held ever since.

Prof. Cooke never had the advantages of a European education, or indeed of any systematic teaching in science. He acquired his taste for chemistry at the early lectures of the Lowell Institute, in Boston, given by the elder Silliman, and, with the apparatus he had collected in a little laboratory in his father's house while a boy, he began his first course of lectures at Cambridge. For several years preceding his appointment no regular instruction in chemistry had been given to the undergraduates, and he had, therefore, the whole labor of developing this department of the college from the begin-

ning. Although scientific schools had been previously established, both at Cambridge and at New Haven, yet Prof. Cooke was probably the first to introduce into our American colleges the experimental method of teaching physical science. He was, at first, greatly hampered by the inflexible recitation system, then universal, and success was only gained after many trials; but Harvard College may now claim to offer its undergraduates as broad and thorough instruction in the various departments of chemistry, including mineralogy, as any similiar institution in the world. Like most American men of science, Prof. Cooke's first duty was to teach, and his time and energy have accordingly been chiefly spent in developing methods of science-teaching, in building laboratories, in making collections, and in providing the various means of scientific instruction.

In connection with his teaching Prof. Cooke has published the following books:

"Chemical Problems and Reactions, to accompany Stöckhardt's Elements of Chemistry," in 1857; "Elements of Chemical Physics," in 1860; "Principles of Chemical Philosophy," in 1869.

In a notice of the last book the London *Chemical News* says: "So far as our recollection goes, we do not think that there exists in any language a book on so difficult a subject as this, so carefully, clearly, and lucidly written;" and in noticing the same book the *American Journal of Science* says: "To Prof. Cooke, more than to any American, is due the credit of having made chemistry an exact and disciplinary study in our colleges."

Prof. Cooke has given many courses of popular lectures in different cities—Lowell, Worcester, Brooklyn, Baltimore, and Washington—besides five courses at the Lowell Institute in Boston. His course of lectures at the Brooklyn Institute, in 1860, was subsequently published under the title of "Religion and Chemistry; or, Proofs of God's Plan in the Atmosphere and its Elements" (1864). In these discourses he aimed to show that the argument for design is not invalidated by the theories of evolution.

A course of lectures on electricity at the Lowell Institute, Boston, in the winter of 1868–'69, was followed by the publication, in the *Journal of the Franklin Institute*, of a series of papers on the "Absolute System of Electrical Measurements" and on the "Theory of the Voltaic Battery." In the last he developed a new theory of electricity, which has also been embodied in the later editions of his "Chemical Philosophy." This theory, like that of Dufay, admits two electrical fluids; but it regards these as separable constituents of the ether of space. These ethereal fluids, more or less blended, form an atmosphere around every molecule held in place by the immense force of molecular attraction; and when, by the various causes of electrical disturbance, the electrical ethers become more or less isolated on the same or on different molecules the two tend to flow

together with great rapidity in virtue of their wonderful elasticity. If we assume that this motion takes place in accordance with the well-known laws of the diffusion of gases, the theory gives a satisfactory explanation of all well-established electrical phenomena.

In the autumn of 1872 Prof. Cooke delivered an interesting and important course of lectures on the "New Chemistry," which was subsequently published in the "International Scientific Series." His volume is one of the best and most successful of these books, and has been very highly appreciated both in this country and abroad, having been translated into most of the languages of Europe.

Among Prof. Cooke's lesser scientific publications may be mentioned the following:

1. "On the Relation between the Atomic Weights of the Chemical Elements" ("Memoirs of the American Academy," vol. v., 1854).

It was first shown in this paper that when the elementary substances are classified in natural groups, their atomic weights and other physical qualities are related by regular differences.

2. "On Two New Crystalline Compounds of Zinc and Antimony, and on the Cause of the Variation of Composition observed in their Crystals" ("Memoirs of the American Academy," vol. v., 1855).

This investigation proved that the crystalline form of these compounds was preserved under very considerable variations of composition, and indicated that the excess of one or the other constituent depended not solely on the composition of the menstruum in which the crystals were formed, but also on the chemical force which determines the union of the elements in definite proportions. The subject was still further discussed in the following paper, published during a visit to England.

3. "Crystalline Form not necessarily an Indication of Definite Chemical Composition, or on the Possible Variations of Composition in a Mineral Species independent of the Phenomena of Isomorphism" (*Philosophical Magazine* for June, 1860).

4. "On the Dimorphism of Arsenic, Antimony, and Zinc" (*American Journal of Science* for March, 1861).

It was here proved that all three of these elements are capable of crystallizing in octahedrons of the regular system.

5. "On Octahedral Galena" (*American Journal of Science* for January, 1863).

In this it was shown that the octahedral cleavage in this singular variety of galena from Lebanon County, Pennsylvania, is merely an unusual development of a constant condition.

6. "Crystallographic Examination of the Hebron Childrenite, and Comparison of this Variety with the Childrenite of Tavistock" (*American Journal of Science* for September, 1863).

7. "Crystallographic Examination of the Acid Tartrates of Cæsia and Rubidia" (*American Journal of Science* for January, 1864).

8. "On the Projection of the Spectra of the Metals" (*American Journal of Science* for September, 1865).

9. "On the Construction of a Spectroscope with a Number of Prisms by which the Angle of Minimum Deviation for any Ray may be accurately measured" (*American Journal of Science* for November, 1865).

10. "On the Heat of Friction" ("Proceedings of the American Academy," 1865).

11. "On the Aqueous Lines of the Solar Spectrum" ("Proceedings of the American Academy," 1866).

By comparing observations with the spectroscope and the hygrometer, it was in this paper first shown that a large part of the air-lines in the solar spectrum are due to aqueous vapor.

12. "On Danalite, a New Mineral Species from the Granite of Rockport, Massachusetts" (*American Journal of Science* for July, 1866).

This is a well-marked species allied to Helvin, but containing zinc in place of manganese.

13. "On Cryophyllite, a New Mineral Species of the Mica Family, with Some Associated Minerals in the Granite of Rockport, Massachusetts" (*American Journal of Science* for March, 1867).

Besides establishing a new species, this paper shows that in the veins of the Rockport granite there are closely associated a unisilicate and a bisilicate mica, which are isomorphous with each other, a circumstance which renders probable the theory that the wide variations in the composition of the micas may result from an isomorphous mixture of two similar types.

14. "On Certain Lecture Experiments, and on a New Form of Endiometer" (*American Journal of Science* for September, 1867).

15. "A Method of determining the Amounts of Protoxide of Iron in Silicates not soluble in the Ordinary Mineral Acids" (*American Journal of Science* for November, 1867).

16. "Crystallographic Determination of Some American Chlorites" (*American Journal of Science* for September, 1867).

The paper gives some new measurements of angles, and shows that there are two crystallographic types of chlorites corresponding to the well-known types of micas. It is further shown that there is a variation of optical angles in the chlorites, even on the same specimens, like that observed with the micas, and the inference is drawn that the variation is due to a similar cause.

17. "Atomic Ratios" (*American Journal of Science* for May, 1869).

It was for the first time pointed out in this paper that what mineralogists have long called the oxygen ratio of a silicate is really the ratio between the atomicities of the acid and basic radicals in these salts.

18. "The Vermiculites—their Crystallographic and Chemical Relations to the Micas, together with a Discussion of the Cause of the Variation of the Optical Angle in these Minerals" ("Proceedings of the American Academy," 1873).

This monograph contains the chemical analyses and crystallographic descrip-

tions of several micaceous minerals which are here classified together, and shows that the variations of the optical angle in the micaceous species is due to the interfoliation of the different members of a macle. It also points out the close relation between hexagonal and trimetric crystals by showing that a hexagonal form and structure may result from a similar macling of trimetric crystals the prismatic angle of which is 120°.

19. "Melanosiderite, a New Mineral Species from Mineral Hill, Delaware County, Pennsylvania" ("Proceedings of the American Academy," 1875).

20. "On Two New Varieties of Vermiculites, with a Revision of Other Members of this Group," published in connection with F. A. Gooch ("Proceedings of the American Academy," 1875).

21. "On a New Mode of manipulating Hydric Sulphide" ("Proceedings of the American Academy," 1876).

This in application of the soda-water fountain, by which hydric sulphide is dissolved in water under pressure, and the magnet readily applied in a concentrated form.

22. "On the Process of Reverse Filtering, and its Application to Large Masses of Material" ("Proceedings of the American Academy," 1876).

This enumeration occupies but a small space; but when it is considered that each paper only states the results of elaborate and protracted original and experimental investigation, where the unverified guesses and the trials that go for nothing do not appear, we can form some idea of the amount of labor involved in the quiet life of a true scientific man.

Prof. Cooke has also written various articles for encyclopædias and reviews, and published several addresses. His discourse on "Scientific Culture," delivered at the opening of the summer courses of instruction in chemistry, at Harvard University, July 7, 1875, printed in THE POPULAR SCIENCE MONTHLY for September, 1875, and republished in London, was one of the ablest contributions to the literature of scientific education that have appeared in a long time. Prof. Cooke's life has been one of valuable scientific service, which has, moreover, met with wide and cordial appreciation. He has been honored by the membership of many learned societies in this country and in Europe, and was quite recently elected foreign honorary member of the Chemical Society of London.

EDITOR'S TABLE.

HONOR TO ADAM SMITH.

ABOUT a hundred gentlemen sat down to dinner at Delmonico's, December 12th, in commemoration of the centennial anniversary of the publication of Adam Smith's "Wealth of Nations." The occasion was an interesting one, and the various topics suggested were treated with an earnestness and ability of which the public got but a very imperfect idea through the newspaper reports. Mr. Parke Godwin presided with efficiency, and made a very instructive opening speech, which was followed by addresses from Mr. Bigelow, Mr. Atkinson, Mr. D. A. Wells, Prof. Sumner, and Dr. Anderson, of the Rochester University, each of which brought out an important aspect of the great subject of free-trade. While Adam Smith was honored as the chief historic representative of rational and liberal views in regard to the liberty of commerce, it was pointed out that his position may be easily misconceived, and his claims exaggerated. Without denying the proposition of Mr. Buckle, that Smith's "Inquiry into the Nature and Causes of the Wealth of Nations" is probably the most important book in its influence upon the policy of states and the economical welfare of mankind that was ever written, it was shown also that Adam Smith was but the mouthpiece of his age; that a preceding generation of inquirers had prepared for him; that the French economists were in advance of Europe in their economic views; and that an elaborate French work appeared in 1776, simultaneously with the "Wealth of Nations," in which the same conclusions were reached, and enforced with great clearness and power. As stated by Mr. Bigelow, it was but another case so common in the progress of scientific investigation, where the ideas reached belong rather to the epoch than to any individual exponent of them.

Mr. Wells gave an admirable account of the workings of the restrictive system, which burdened the industries of Europe from the middle ages down to the time of Adam Smith. He showed that the fundamental idea in all business transactions, whether between nations or individuals, was that parties trading were in necessary relations of enmity, and that what one man or one nation gained the other party inevitably lost. So radical was this antagonism regarded between men, guilds, and different countries, as to find expression in Hobbes's theory that the state of man in society is one of necessary and perpetual war. The merit of Adam Smith was, that he demonstrated the utter fallacy of this view, and proved that by the natural laws of trade the advantages of exchange are mutual, and that in its largest possible freedom there will accrue the largest possible benefits to all. Christianity had been trying for many centuries to enforce the golden rule of mutual justice as a matter of duty, to be carried out even though it involve suffering and loss; Adam Smith showed that the rule of right in human intercourse, so far as trade is concerned, produces reciprocal good, and is for the pecuniary interest of both parties.

Dr. Anderson maintained forcibly and impressively that free-trade is to be placed on the broadest grounds of morality. The liberty of commerce he held to be a God-given right as much as any other kind of liberty; and the restrictions upon trade to be just as immoral and vicious as interference with other forms of freedom. A man

has a natural and inalienable right to his personal freedom of action, to the use of his muscles, and the employment of his powers, in any manner and direction that he chooses; to contravene this is slavery. A man has a right to the use of his mind, to freedom of thought and speech; and to interfere with this is tyranny. A man also has a natural right to freedom of exchange of the products of labor, to buy and to sell, as he pleases and where he pleases; and every arbitrary impediment to this liberty is despotism. In the advance of civilization, and through the struggles of ages, personal liberty of action and thought has been secured; but it still remains to extort from governments absolute freedom of commercial intercourse, whether on a small scale or large. Dr. Anderson paid a compliment to the great abstract thinkers—Grotius, Smith, and Bentham—who, although only scholars and philosophers, have exerted a powerful influence upon the modern world; and he stated that free-trade doctrines are now taught in all our best colleges so efficiently that this influence will be certain to tell in the future settlement of the question.

Prof. Sumner took up, briefly, the present state of political economy, and remarked upon its incompleteness and the conflict of views that has recently sprung up in regard to its scope, its validity, and its permanence. While many of its questions will have to be further elucidated, while much that was at first laid down as true has required revision, and while other forms of knowledge are reacting upon and modifying it, Prof. Sumner is of the opinion that political economy must stand in the future as an established division in the classified hierarchy of the sciences.

Mr. Sanborn, of Boston, followed this line of thought in some remarks on the relation of political economy to social science. In that closer interdependence of the various forms of knowledge which has resulted from scientific investigation our views become enlarged, and it is apparent that these subjects must more and more be considered together. Political economy will suffer if studied exclusively, or with no reference to that philosophy of man and society of which it is but a part.

Dr. Leverson closed the speech-making by an appeal to introduce the study of the rudiments of political economy in our schools. He testified, from his own large experience as a lecturer, both in England and in this country, that pupils in schools may be very early interested in an elementary knowledge of economics, or of the sources of familiar things and the business operations by which they are procured. He thought this was the proper place to begin the study of social science.

SOCIETIES FOR THE DIFFUSION OF SCIENCE.

The necessity of associated action for the attainment of desirable and important public objects is generally understood, as is shown by the numerous societies and organizations for the promotion of religious, political, philanthropic, literary, historical, and scientific objects. The directions taken by such associations in respect to the interests to be promoted are, of course, various, and well represent the state of intelligence, the culture, the mental preoccupations and aspirations, of the community in which such societies are formed. As regards science, the organization of societies for its promotion has mainly had for its object the encouragement and aid of original observation and research; and, as men devoted to independent inquiry are not numerous, and are widely scattered, such associations are neither large in number nor strong in their member-

ship and support. Moreover, from the nature of their objects they are more completely cut off from public interest, sympathy, and patronage, than any other societies. In speaking of the meeting of the American Association for the Advancement of Science, held at Buffalo last August, we called attention to the duty of scientific men to take the public more into the account in the organization of their work, and we showed how that might be done without any detriment to the proper objects which the convention had before it. Of all the subjects that are now promoted by social combinations, that of the *diffusion* of science owes the least to such agencies. The work of disseminating scientific knowledge among the people goes slowly on, by means of the press, by schools, and by lectures; but it would be much more vigorously prosecuted if it were made a distinctive and prominent object, either in associations expressly formed for the purpose, or in societies that combine different lines of effort in the general purpose of popular instruction. It is gratifying to note the multiplication of scientific academies in the leading cities of the country, which bring together observers and investigators, and call out original contributions that prove to be valuable and worthy of publication in an annual volume of "Transactions." But such associations can only be sustained at the larger centres of population, and even there they must struggle hard to maintain their existence. But if these bodies embraced within their plans, as a leading and permanent object, the diffusion of science through the community and the scattering of valuable information upon practical subjects, there can be little doubt that they would be better sustained, both by attendance at their meetings and by the contribution of funds to carry on their operations. Moreover, in the smaller cities and towns, where the higher work of science is impracticable from the fewness of its cultivators, societies promotive of popular scientific education might be created that would do efficient and valuable service. Scientific libraries might be collected, scientific essays contributed, and followed by instructive discussions, and courses of lectures secured from competent men on subjects that would enlist the attention and secure the liberal patronage of the public. In every town of five or ten thousand inhabitants a dozen active, thoughtful, and spirited men might be found, competent to organize and manage such a society, that would effect much good in the locality; and, if adjacent towns did the same thing, much might be gained in various ways by coöperation. Only one thing is needed to achieve this result, and that is, a hearty interest and some enthusiasm in the enterprise on the part of a few individuals to carry it on.

We by no means claim that such an association should be exclusively scientific in its aims. It might embrace literature, local history, political economy, and various social questions, among its objects. We only urge that the popular diffusion of scientific information should be an essential element and a clearly-recognized object. From such modest and perhaps ill-defined beginnings valuable and lasting institutions have often arisen. We have met with some remarks in a paper on the "Historical Societies of the United States," contributed to the Report of the Bureau of Education in Washington by Dr. Henry H. Holmes, Librarian of the New York State Library at Albany, which are so suggestive in relation to this subject that we take the liberty of quoting them:

"To these observations on the question of enlarged plans for local societies, we venture to subjoin the further inquiry, whether most county and town societies might not, with incalculable advantage, combine with

historical research the study of science, art, and natural history? Every locality already has its military, fire, debating, literary, social, or charitable society. It is incredible that there should be so few simply for the pursuit of knowledge to the acquisition of which all men are so naturally impelled and in which they manifest so deep an interest. The same motives, which dispose some of the leading minds of a place to associate for the sake of preserving its history, must be operating in the minds of others, their neighbors, to desire to acquire and communicate knowledge in other forms. On the part of those interested in history it should be regarded as a strong reason for extending the scope of their society, the consideration that when confined to a single subject it will depend for its permanence on the activity of two or three members. It does not afford a basis sufficient for the active coöperation of more than a small portion of the cultivated minds of the place; the topics either soon become exhausted as matters of continual research, or the information is meagre and accumulates slowly, and the popular interest diminishes; the meetings cease to be attended, and the society either dies of inanition or languishes while standing in the way of a new organization on a more comprehensive plan.

"It may be urged as an objection that some of our societies have commenced with the title of 'historical and philosophical,' and have not been remarkably successful. Others, however, have tried the plan of conjoined aims, and congratulate themselves on the result. The Essex Institute of Salem, Massachusetts, was formed in 1848 from the union of a county historical and a county natural history society, and organized on a popular basis of large membership, having at the present time four hundred and eighty members. With the aid of historical and scientific workers it is prosecuting both branches with an efficiency, as shown by its publications, which must compel imitation. The Albany Institute, New York, has been perpetuated with varying fortunes for forty-six years, and has four departments of research—physical science and the arts, natural history, history, and general literature. It has at no time been so promising an organization as at the present, when it has been extended to a membership of two hundred and four. A similar successful society is the Literary and Philosophical Society of Liverpool, England, founded in 1846, which has over two hundred members, and has published twenty-eight volumes of its 'Transactions.' The subjects treated of in these conform, in fair proportion of literature, history, and science, to the name of the society. One motive assigned in its constitution for organizing the society, 'to modify the local tendency to the pursuit of commerce,' is capable of receiving a wider application.

"We have purposely alluded to the large membership in these three societies, because a late scientific writer, speaking of the frequent failures of the learned societies of the United States, declares that they have died from 'a constant enlargement of the range of membership, and consequent lowering of the tone of the society' (*North American Review*, October, 1874). And yet we draw from this same writer the two facts that the membership of the leading English societies ranges from four hundred to one thousand or several thousand members, and that the annual tax on each member is from two to four guineas. We should infer from these facts that, by a large membership, an abundant income is secured for the purposes of a society, and that the original papers of the men of science who are joined with them can be published, and the expense of their investigations provided for. A large membership secures friends, an audience, an income, and elevates the purposes and aims of all. Some aid by active efforts, some by pecuniary help, and all by the sympathy of a common purpose. Membership is not a reward of merit, acquired for achievements in literature or science, but an encouragement and a stimulus both to the less learned and the most learned. It ought not to be difficult to combine the man of research with the intelligent aspirant for knowledge, who educates himself for similar researches by means of the companionship. To the man of science or invention it must be desirable that he should have the encouragement of a listening audience, and be brought in contact with men of varied pursuits, outside of his specialty. It affords him an opportunity at least to utter his words of scientific truth before his fellow-citizens. To make an addition to the sum of human knowledge, or to diffuse and inspire a love of it, may be of equal importance to humanity.

"In suggesting this combination of varied objects of pursuit, we are not, of course, supposing that academies of scientists can be founded everywhere; but we cannot resist the belief that in most counties and towns there will be found a sufficient number of men of education, of all professions, occu-

pations, and opinions, disposed to unite for the mutual pursuit of history, science, and the arts; and that they will engage in it, not in a spirit of exclusiveness, but of benevolence, aiming to develop a love for the most elevated and accurate forms of knowledge. It should be easy, in a multitude of places, for associations formed with these blended purposes to sustain twice a month, or even weekly, during a large part of the year, meetings for the purpose of listening to papers, original or compiled, from members or invited speakers, or for the discussion of any topic introduced. By some such method as this, local societies would become schools of thought and learning for the active members of the community in hundreds of our towns and cities. There might naturally follow a union of the societies of a State under a general society, for the publication of such papers as might be deemed suitable.

"The extensive formation of such societies throughout the land seems so full of promise and so potent for good as to justify the establishment of a national society for the organization of associations for the pursuit of knowledge. Such a society might initiate efforts which would have the cordial support of co-workers in every State of the Union. The original name of our oldest learned society, the American Philosophical, of which Franklin was the first president, was 'The American Society for Promoting and Propagating Useful Knowledge.' The title is an indication of the expanded and benevolent designs of its founders. This society had, also, its standing committee on history and commerce. If the Smithsonian Institution, founded 'for the increase and diffusion of knowledge among men,' should be able to incorporate, with its present benefactions to science, the support of an agency for encouraging such societies as have been described, it might be hoped it would not be a departure from the spirit of its founder. It would be an agency, by whatever association it should be controlled, for introducing and promoting a plan for enlisting tens of thousands in the direct study of science, art, and history. Such societies would be the means of educating many communities to a loving appreciation of scientific investigations, and of correct views of human history. They would contribute incalculably to the progress of American society and to the happiness of millions."

LITERARY NOTICES.

Elements of Physics, or Natural Philosophy. By Neil Arnott, M. D., LL. D., F. R. S. Seventh edition, edited by Alexander Bain, LL. D., and Alfred Swaine Taylor, M. D., F. R. S. New York: D. Appleton & Co. Pp. 873. Price, $3.

We are glad to see this sterling and favorite work brought up to date, as it is in the edition now issued. A generation ago Arnott's "Physics" was the leading text-book on natural philosophy both in England and this country, and we much question if for educational purposes anything equal to it has appeared since. We have physical text-books with finer pictures, but we have gone to an excess in this direction, and greatly overdone the pictorial element. It is an objection to large, elaborate, and profuse illustrations, that they are costly, that they trench upon the text, and often give prominence to trivialities, simply because they afford an opportunity for a showy engraving. The illustrations of a high-grade scientific book should be simple, and severely subordinated to the ideas they exemplify. The cuts in Dr. Arnott's book, while having no merit as mere pictures, are perfectly sufficient for their purpose of illustration.

There is another objection to our recent text-books of physics in the want of balance or proportion in treating of subjects. The rage for the new, and what is called keeping up with the times, has led to undue prominence in representing the last results of science, and to a corresponding neglect of those established facts and principles which have lost their novelty because they are old and well-settled. A book filled with the recent wonders of research may be exciting, and full of interesting information, but these qualities cannot commend it to students whose object is to acquire the body of principles that constitute a science. In this respect, and in physics especially, the value of the old greatly preponderates over that of the new. No doubt such works should be up to date, and represent "the present state of science," but facts discovered a great while ago, and long-determined laws, are quite as much parts of the present state of science as the last results of in-

quiry. In this respect, also, Arnott's "Elements of Physics" is more harmonious and well-proportioned than many of the later works upon the subject. Its careful editors have brought it up to date by introducing clear accounts of the various advances in physics that have been made during the last twenty years. The modern doctrines of Energy, Correlation of Forces, the Mechanical Theory of Heat, the Kinetic Theory of Gases, Barometric Gradients, Weather Areas, and Storm-signals, Tyndall's and Helmholtz's Acoustical Investigations, Spectrum Analysis, the Radiometer, and many other results of research in recent years, are all introduced in their appropriate places, and briefly and succinctly explained. But they fall into their proper relation as but a small part of the great system of truths that must now be comprised in any standard treatise upon the science of physics. The editors, we observe, have caught the spirit of the work, and assimilated the new matter to the method of exposition adopted by the author.

And it is in this that the unrivaled merit of Dr. Arnott's work chiefly consists. The style in which it is written, as is well known, is a model of easy simplicity. It is the most *readable* book on natural philosophy that we have in the language. Another admirable feature is the copiousness and diversity of its illustrations and concrete applications of physical principles. These are mainly drawn from the familiar field of every-day life, and, notwithstanding the numerous books that have appeared on common things, familiar science, etc., Arnott's "Physics," is still our best book of this kind. He has been much copied, but his statements have not been improved upon. The new edition of this work may therefore be strongly recommended to schools as a text-book, a reference-book, or a reading-book, and, however used, it will be pretty sure to do good service.

Modern Physical Fatalism, and the Doctrine of Evolution, including an Examination of Mr. Herbert Spencer's "First Principles." By Thomas Rawson Birks, M. A., Knightbridge Professor of Moral Philosophy, Cambridge. New York: Macmillan & Co. Pp. 311. Price, $2.25.

We have here another attempt to demolish Herbert Spencer, and it is noteworthy chiefly as emanating from a dignitary of the University of Cambridge. Those in quest of objections to Spencer's system, and not very particular about their quality, will find in this volume a great deal of material adapted to their purpose. But as a polemic it is by no means equal in subtilty, force, or originality, to various replies to Spencer that have previously appeared. In our judgment, it is quite inferior in logical acuteness to Prof. Bascom's criticism in the *Bibliotheca Sacra* of last October, while in candor, courtesy, and philosophic liberality, the English author is not for a moment to be compared to the American reviewer. The book is dominated by an intense theological bias, and is written from the standpoint and in the interest of the most unmodified type of orthodoxy. The author writes in behalf of such vast interests that he cannot be trusted. Absorbed in the interests of the eternal world, he is lax and careless about the things of this world—does not represent them as they are. In the first chapter, and on the very first page, he says that in Spencer's system of thought "science is identified with physics," and that this is the way he reconciles religion and science. This, of course, is absolutely false, and not only so, but it is a misrepresentation so fundamental as to taint the work through and through. A writer who would commit so flagrant a misrepresentation at the threshold of his work forfeits at once his claim to the confidence of intelligent readers, who will see that a discussion so vitiated and loosely carried on is not worth pursuing.

Dr. Birks makes wholesale objections to the doctrines of the Unknowable, the Relativity of Knowledge, the Indestructibility of Matter, the Conservation of Force, Evolution and Natural Selection, and closes his book by saying: "The doctrine of the Unknowable is a lower depth in the scale of intellectual and spiritual darkness than the old Athenian idolatry. The Persistence of Force, and the Indestructibility of Motion, when set up to replace the true and living God of the Bible, the Almighty Creator of heaven and earth, will be found on inquiry to be still meaner and more worthless than the old heathen idols of wood and stone. One sentence of the Word of God, in the song of the heavenly elders, lays the foun-

dation of a philosophy nobler and deeper than all the human counterfeits of these latter days."

Winds of Doctrine: being an Examination of the Modern Theories of Automatism and Evolution. By Charles Elam, M. D. London: Smith, Elder & Co. Pp. 163.

This is a work of a similar stripe to that just noticed. The contents of the volume first appeared in the *Contemporary Review*, in three articles, and coming from a medical man, the presumption should be that it is a scientific discussion, but it is rather a piece of violent rhetorical denunciation. The author contributes nothing to the scientific illumination of the subject, and takes his cue from some of the outgivings of Prof. Mivart in his recent criticisms of Darwinism. But while Mr. Mivart, like most of the eminent biologists of the time, admits evolution as a great historic fact of Nature, however deficient may as yet be its explanation, Dr. Elam scouts it in every form and degree as a pure figment of the imagination, and an idle absurdity. His virtual position is, that the naturalists are under an hallucination, and that Darwin, Huxley, Tyndall, and Spencer especially, to whom he gives his main attention, are little better than fools so far as *this* subject is concerned. Like Prof. Birks, Dr. Elam writes in the interest of popular traditions and for miscellaneous readers, and has no scruple about his course so he can make out a specious case. He quotes Huxley copiously, but prefers to use his cautious statements, made twelve or fifteen years ago, rather than his later utterances which represent the progress that has been made within that time. With equal unfairness he goes back to Spencer's "Social Statics," published twenty-six years ago, and quotes opinions which Mr. Spencer has stated that he now holds only with important qualifications, instead of judging him by the work upon the same general subject that he is now elaborating.

The spirit here evinced is that of the advocate and partisan, rather than of the candid and earnest inquirer after truth.

There are difficulties with evolution, many, and various, and formidable; and none better understand this, or more freely acknowledge it, than those who have studied the subject most profoundly. There are not only inherent difficulties in the discussion from imperfect knowledge, but there are extrinsic difficulties in bringing before the general mind the nature and force of its proofs, and from its conflict with long-established and widely-cherished beliefs. It is therefore a perfectly easy thing to make objections to the doctrine which many will think annihilating. It is an easy thing to accumulate and ring rhetorical changes on old objections, and with a little license of misrepresentation, and a fresh battery of depreciatory adjectives, to make out a killing case in the estimation of those whose minds are made up beforehand, and who know little of the real issues of the subject. If, on any plain and simple question, arising out of an open transaction between two neighbors who have become involved in law, the hireling attorneys can so confuse and confound all common-sense that a jury is as likely to give a wrong verdict as a right one, what may we not expect when a great, complex, wide-reaching, and newly-presented scientific question becomes a matter of controversy before ill-instructed people, with loud and angry protestations that it involves the very existence of morality, religion, and God? The skillful counselor, who cares only to produce an impression, has obviously a great advantage here.

But while the pert and supercilious critic is carrying all before him, and proving to those who knew it all before that evolution is a baseless fancy, a mere transient gust of wild and absurd speculation, the disciplined, sober-minded, and thoroughly-instructed naturalists, guided by the light it affords, are penetrating deeper into the secrets of phenomena, making further discoveries, and rapidly extending the bounds of our knowledge of Nature.

Inventional Geometry. A Series of Problems intended to familiarize the Pupil with Geometrical Conceptions, and to exercise his Inventive Faculty. By William George Spencer. With a Prefatory Note by Herbert Spencer. New York: D. Appleton & Co. Pp. 100. Price, 50 cents.

This is a small and a modest book, but a very important one for all who have a concern about the quality and character of education. It is not a book that will work

well in our smooth-running educational system—not a machine that can be belted on in some convenient corner of our educational cotton-mills. In the objects it aims to secure, and in the method of attaining them, it is outside of the customary school routine. It is a contribution to the momentous and much-neglected work of self-education to which the school-room, as commonly managed, is not very favorable.

The author of this little work, the late W. G. Spencer, of Derby, England, was a mathematical teacher, and a gentleman of wide cultivation and independent opinions. He had been for many years an instructor, and entertained quite unconventional views on the subject of education. He maintained that, of all that passes under the name, only that is truly education which calls out mental exertion, trains the pupil to the exercise of his own faculties, develops the judgment, and gives the student the ready use and command of his own mind. It is, therefore, necessary constantly to throw the pupil back upon himself, and, while encouraging and guiding him, leave him at the same time to do his own work. For the usual occupations of the school-room, explanatory instruction, loading the memory with the contents of books, and helping the pupil rapidly along by all kinds of facilities and devices, Mr. Spencer had but little respect; and he measured the excellence of the teacher by his faculty and resources for awakening the pupil's interest, keeping him judiciously occupied, and inciting him to use, cultivate, and strengthen his own powers.

In the later years of his teaching, Mr. Spencer was much occupied in giving private instruction in mathematics, and he was therefore brought into constant contact with individual minds, and enabled to study them much more critically than if he had been dealing with classes in the usual way. In these circumstances he devised a course of exercises in elementary geometry for the use of beginners, designed to lay the foundation for mathematical study, and at the same time to cultivate the faculties of invention and construction, which are of the highest importance, and almost totally neglected in the common methods of the schools. As this course of exercises began with the simplest problems, and was skillfully graded so that the pupil could do the whole work himself, there seemed to be no reason why the benefits of the method should not be extended to all who might wish to avail themselves of it, and it was so highly appreciated by those who had used it that the author was at length induced to print it, although he had no such intention at the time of its preparation. The "Inventional Geometry" is now republished, and being a very suitable book for companionship with the "Science Primers," now being issued from time to time, the publishers have thrown it into the same form, and included it among the reprints in this elementary series. But in one respect the "Inventional Geometry" differs from the little books with which it is associated. The Science Primers are highly estimated. They fall in with the stereotyped habits of the class-room, and may be easily learned by heart like history, grammar, or the catechism. This book will, however, enforce a different treatment, and if the object of education be the discipline of the mental faculties through honest effort, and if thorough familiarity with geometrical conceptions be desirable, and the training of the inventive and constructive faculties be valuable and important, the Primer of Geometry will be worth more than all its associates put together. We recommend it to those who are thoughtful and conscientious in educational matters. Any fair-minded boy or girl of twelve or fourteen years of age can go through it without difficulty, and cannot get through it without gaining the advantages it aims to secure. Those who work their way through it will be certain to know one thing thoroughly, and, as Goethe said to Eckermann, "It is always an advantage to have any clear bit of knowledge."

The author of this book was the father of Herbert Spencer, who testifies from observation and experience to the excellence of the method, as will be seen by the following note to the publishers:

"London, *June* 3, 1876.

"Messrs. D. Appleton & Co.: I am glad that you are about to republish, in the United States, my father's little work on 'Inventional Geometry.' Though it received but little notice when first issued here, recognition of its usefulness has been gradually spreading, and it has been adopted by some of the more rational science-

teachers in schools. Several years ago I heard of its introduction at Rugby.

"To its great efficiency, both as a means of producing interest in geometry and as a mental discipline, I can give personal testimony. I have seen it create in a class of boys so much enthusiasm that they looked forward to their geometry-lesson as a chief event in the week. And girls initiated in the system by my father have frequently begged of him for problems to solve during their holidays.

"Though I did not myself pass through it—for I commenced mathematics with my uncle before this method had been elaborated by my father—yet I had experience of its effects in a higher division of geometry. When about fifteen, I was carried through the study of perspective entirely after this same method: my father giving me the successive problems in such order that I was enabled to solve every one of them, up to the most complex, without assistance.

"Of course, the use of the method implies capacity in the teacher, and real interest in the intellectual welfare of his pupils. But given the competent man, and he may produce in them a knowledge and an insight far beyond any that can be given by mechanical lesson-learning.

"Very truly yours,

"Herbert Spencer."

The Geographical Distribution of Animals, with a Study of the Relations of Living and Extinct Faunas as elucidating the Past Changes of the Earth's Surface. By Alfred Russell Wallace. Two vols. With Maps and Illustrations. New York: Harper & Brothers. Pp. 1110. Price, $10.

This work has grown out of the recent progress of biological science, and could neither have been produced earlier than it has been, nor probably by any other living author. To those who regard the evolution hypothesis as a piece of mere useless speculation, it may be replied that it is the most powerful stimulus to investigation in the higher science of living things that has yet been known, of which the noble work before us is incontestable proof. The problem of animal distribution is here so conceived and presented as to give it very much the character of a new subject.

Up to this time, a naturalist has only needed to try to learn about the fauna of any country to be made aware of our lack of knowledge in this field. Much has been learned, of course, but the records were fragmentary and scattered, and it was only on the shelves of the best zoölogical libraries that anything approaching completeness was to be found, so that practically such information has been inaccessible. But with the growing interest in Darwinism there came an appreciation of the value of the study of distribution, and a demand arose which made itself felt. As is always the case, the demand only needed to become urgent to insure a supply. And it was to meet this want, growing daily more pressing, that Mr. Wallace put forth this work—and the task could not have fallen into better hands. His life has been one of preparation for it. As early as 1848 he embarked with Mr. H. W. Bates for the Amazons, and in that region—the richest in animal life—and later in the Malay Archipelago, the best years of his life were given to the study of zoölogy. Few of our readers need to be reminded that in those far-away lands he independently worked out the theory of "natural selection." The more difficult work of establishing the validity of the "doctrine of descent" fell into other and, as Mr. Wallace modestly and gracefully says, abler hands; but he has not ceased to work in that field, and has given great aid in searching out relevant facts and showing their bearings. This work is certainly one of the most valuable of these contributions. From the scattered sources he has, with infinite pains, collected the details of that which was known, and, arranging them with a skill and method which leave little to be desired, has put them within the reach of all.

The book sets out with an introductory chapter, showing the inadequacy of the popular notion that the manner in which animals are dispersed over the globe is due to diversities of climate and vegetation. Much as there undoubtedly is to give rise to this belief, a little examination shows that no such off-hand treatment will do. That South Africa has lions and giraffes, and Australia kangaroos and other marsupials, finds no explanation in differences of soil and climate, because no marked differences exist. So, too, the theory fails when we find Europe destitute of raccoons, opossums, and humming-birds, and North America without hedgehogs or true fly-catchers, although the conditions of life are in all essentials similar in the two regions.

Assuming the view that each species

has had one birthplace, and only one, the second and third chapters discuss the means by which dispersal has been effected, and what bearing the surface-changes of the earth have had on distribution. They are of great interest, and admirable examples of the efficiency of scientific induction when applied by able hands to the solution of perplexing problems.

The principles upon which zoölogical regions should be formed are next considered, and the reasons given which led the author to adopt, with little change, the divisions proposed by Mr. P. L. Sclater in 1857, which maps the globe into six great primary regions, the Palæarctic, Ethiopian, Oriental, Australian, Neotropical, and Nearctic.

Zoölogical classification receives, as of course it should, due consideration. Mr. Wallace attempts no reconciliation of the disputed points of classification, but selects and tabulates for his uses a few of the best-known classes. As the title-page indicates, the relation and distribution of extinct faunas have an important place. The recent lectures of Prof. Huxley are too fresh in the minds of our readers for it to be necessary to emphasize the value of the study of fossil forms in connection with the general doctrine of evolution. In the hands of Mr. Wallace its application to the question of distribution is full of suggestion and interest. We may add that, in this connection, due acknowledgment is made of the successful and important labors of American paleontologists.

In Parts IV. and V. are treated, first, the forms of life as seen in the different zoölogical regions, their differences and resemblances being pointed out; with, lastly, a systematic, tabular arrangement of the families of the animals considered, and sketches of their geographical distribution. The value and interest of these volumes are enhanced by a series of twenty plates showing the physical aspect and special zoölogical character of the different sub-regions, and by a set of excellent maps on which are shown the outlines of the regions and sub-regions, the belts of altitude, the forests, pastures, deserts, and snow-lines, together with the contours of the beds of the great oceans as determined by the most recent soundings.

Further Notes on "Inclusions" in Gems, etc. By Isaac Lea. Philadelphia: Collins.

Continuing a communication made in 1869 to the Philadelphia Academy of Sciences, Dr. Lea, in this pamphlet, gives the results of further examination of the crystals and cavities to be found in gems and minerals. His special researches are illustrated by a plate in which are represented cavities of all shapes, with and without fluid contents, crystals of various shapes and maculations in corundum, sapphire of different shades, zircon, moonstone, emerald, where the cavities contained cubic crystals surrounded by a fluid, and beryl with irregular imperfections. The microscopic study of gems must possess great interest to any one whose opportunities allow it.

Essays on Mind, Matter, Forces, Theology, etc. By Charles E. Townsend. New York: Charles P. Somerby. Pp. 404. Price, $2.

The papers which make up this book originally appeared in the *Phrenological Journal* and other publications, and embrace discussions on subjects relating to physics, astronomy, biology, social science, religion, etc. "The essays are chiefly intended to uphold the theory of the stability of matter and forces, and the perpetuity of all minds, as material forces, on a new basis of reasoning, in opposition to the many present vague theories of spirit-minds. Also, as opposed to the assumed origin of matter from nothing, and its inevitable extinguishment in time—not mere change of form and action, but utter annihilation being claimed by some." The author vehemently opposes the "debasing, stagnant theology of over eighteen centuries," deprecates the "folly of Biblical cant," and believes that the "Christian religion is an old-times crude theology and false cosmogony, that ought to be replaced by a more rational and ennobling conception and worship of an infinitely intelligent great First Cause, who is known to us through his creations, and thus inferred attributes of infinite goodness, wisdom, and power."

Various theories are presented in regard to different subjects, which are not wonderful so much for their novelty as for the obscure manner in which they are stated.

There is an air of ultimate truth assumed throughout the essays, which the conclusions hardly warrant; and the author would probably write a better book if he exercised his dogmatic tendencies less and cultivated a clearer style more.

Report of the Condition of the Academy of Natural Sciences of Philadelphia, on moving into its New Edifice, Southwest Corner of Race and Nineteenth Streets. By W. S. W. Ruschenberger. Philadelphia: Collins, Printer. Pp. 56.

The Academy of Natural Sciences of Philadelphia dates from the year 1812, and, at the close of that year, consisted of fourteen members, who assembled on the second floor of a house devoted to millinery purposes. Although their progress was slow, yet, in 1817, the publication of their *Journal* was commenced, and in 1820 they sought more spacious accommodations in a Swedenborgian church. Twenty years later a new building was erected, more space was given to the collections, and an increased number of visitors continued to be attracted. It again outgrew its quarters, and ten years ago a movement was started which resulted in the present edifice. The Academy is now free from debt; it possesses a building constructed with reference to architectural beauty and to the ends for which it was designed, and is apparently in a very flourishing condition. Its cabinets of birds and shells of mollusks are nowhere surpassed in extent and completeness, and in other departments the collections are valuable, though, as yet, comparatively small.

The Structure and Relations of Dinichthys; with Descriptions of Some Other Fossil Fishes. By J. S. Newberry. Columbus: Nevins & Meyers.

Dr. Newberry has reprinted this memoir from Vol. II. of the "Report of the Geological Survey of Ohio," of which we gave a notice last month, and it is accompanied by seven lithographic plates and many woodcut figures. The *Dinichthys*, to which the body of the pamphlet is devoted, is a huge ganoid fish, occurring along the Lake Erie shore in the Huronian shales, and peculiar among its allies in its massive mandibles and in its dentition, which closely resembles that of living *Lepidosiren*. Other resemblances between them are so close as to warrant the belief that in the *Lepidosiren* we have a dwarfed representative of the great fishes which populated the Devonian seas. Dr. Newberry discusses minutely the anatomy and relationships, homologically and generally, of these monarchs among ancient fishes, and describes several additional species. The latter half of the book is occupied with descriptions of new fossil fishes from the carboniferous rocks of Ohio, belonging to various orders and families, all the points of which are elaborated with the close attention characteristic of this distinguished geologist.

In a paper read before the Detroit meeting of the American Association, and now reprinted, Prof. Aug. R. Grote explained the effect of the glacial epoch on the distribution of insects in North America. He endeavors—successfully, we think—to show that arctic forms of insects, the White Mountain butterfly, for example, came southward with the gradual extension of the ice-sheet, and, when the ice-sheet retreated, followed it backward; but some, straying away, or lingering about the local glaciers of high mountain-ranges, gradually followed the declining cold to the high summits, where only could they find a congenial climate. Meanwhile, the surrounding lowlands having become warm, they could not follow their congeners to the arctic zone, but were imprisoned, as it were, on their mountain-tops, and have there remained, undergoing modifications caused by the exigencies of their surroundings. Some such process, Prof. Grote judges, has determined the distribution of most of our Alpine insects.

The Report of the Director of the Central Park Menagerie, Mr. W. A. Conklin, for the past two years, shows that, in spite of the lack of encouragement afforded it by the Park Commissioners, that commendable institution continues prosperous, and is visited by increasing crowds of spectators—among others whole schools, with their teachers, attesting its educational value. The appropriations for it allow of little more than the care of the inmates, but many animals are received on deposit from their owners, and births are constantly oc-

curring. The mortality is low, and becoming less so, owing to improved arrangements and more commodious quarters. The Report contains the usual details of expense and management, and a long list of accessions, which might be of use to visitors in lieu of a guide to the menagerie.

THE TEXTILE COLOURIST: A Monthly Journal of Bleaching, Printing, Dyeing, and Finishing Textile Fabrics, and the Manufacture and Application of Colouring Matters. Edited by CHARLES O'NEILL, F. C. S. Price, $12 per annum.

"The Textile Colourist" was designed by its present editor to bring before the dyers and printers of the different countries such matter as will be of a permanently interesting character to all in the trade. There are embodied in it the results of the most recent investigations and discoveries, arranged in such a manner as to make it a valuable work of reference.

PUBLICATIONS RECEIVED.

Tolhausen's Technological Dictionary, French, German, and English. 3 vols., 900 pages each. New York: H. Holt & Co. Price, $3.50 per vol.

The Electric Bath. By George M. Schweig, M. D. Pp. 134. New York: Putnam's Sons. Price, $1.

Improvements of the Fox and Wisconsin Rivers. By G. K. Warren, Brevet Major-General. Pp. 114, with Plates.

Qualitative Chemical Analysis. By Douglas and Prescott. Pp. 254. New York: Van Nostrand. Price, $3.50.

Geological Survey of the Territories. Vol. X. F. V. Hayden, Geologist in Charge. Pp. 607, with plates. Washington: Government Printing-Office.

Department of Agriculture. Report of 1875. Pp. 536, with plates. Washington: Government Printing-Office.

Calendar of the Tokio Imperial University (1876). Pp. 165.

Preventing the Extension of Syphilis. By J. R. Black, M. D. Newark, Ohio. Pp. 7.

Memorial of Increase A. Lapham. By C. Mann. Pp. 21.

Topographical Surveys and the Public Health. By J. T. Gardner. Pp. 10. Albany: *Argus* print.

Needs of the South educationally. By A. Hogg, M. A. Pp. 24. Salem, Ohio: W. D. Henkle print.

Quarterly Journal of Inebriety. Vol. I., No. 1. Pp. 64. Hartford: Case, Lockwood & Brainard.

History of Spontaneous Generation. By E. S. Dunster, M. D. Pp. 30. Ann Arbor, Michigan: *Courier* print.

Reason and Progress. By J. T. Stewart, M. D. Pp. 18. Peoria, Illinois: *Transcript* print.

Treatment of Eczema. By R. W. Taylor, M. D. Pp. 37. New York: Putnam's Sons.

Hydroadipsia. Pp. 9. Also, The Fever Process in Human Bodies. Pp. 7. By Z. C. McElroy, M. D. Zanesville, Ohio.

Disinfection in Yellow Fever. By C. B. White, M. D. Pp. 16. New Orleans: J. W. Madden print.

Rocky Mountain Locust. Pp. 58. St. Louis: R. P. Studley Company print.

Specialism in Medicine. By E. D. Forée, M. D. Pp. 10. Indianapolis: *Journal* print.

POPULAR MISCELLANY.

Talking by Telegraph.—On Sunday, November 26th, Prof. A. Graham Bell experimented with the "telephone" on the wires of the Eastern Railroad Company between Boston and Salem. Prof. Bell was assisted at the Boston end of the line by two operators, and Mr. Thomas A. Watson by one operator at the Salem end. According to the account published in the *Commonwealth* of Boston, conversation was carried on with Mr. Watson at Salem, by all those present, in turn, without any difficulty, even the voices of the speakers being easily recognized. Whispering was found to be perfectly audible, but was unintelligible. After a time, instead of grounding the wire at Salem, it was connected with North Conway, a distance of one hundred and forty-three miles from Boston, thus leaving Salem as a way-station. After this change had been

made there was a slight diminution in the loudness of the tones, but no difficulty was experienced in carrying on conversation. Another change was made, whereby the electrical current was sent to Portland and back by another line to Salem, thus making Salem a terminal station at the end of nearly two hundred miles of wire. The result of this change was, that the tones of the speakers could be heard, but so faintly as to be unintelligible. With electro-magnets of a higher resistance, Prof. Bell is confident that the sounds would have been perfectly intelligible, the magnets used, it must be recollected, being only intended for a twenty-mile circuit.

How to reach the Pole.—Captain H. W. Howgate, of the Signal-Office, sees no grounds of discouragement in the failure of Nares's expedition to reach the north-pole. The seasons, he remarks, vary in the arctic circle as markedly as in more temperate latitudes, and in a favorable year the ice of the so-called "Palæocrystic Sea" might be broken up. Captain Howgate would have a party of at least twenty hardy, resolute, and experienced men, with provisions for three years, stationed at some point near the borders of the Polar Sea—for instance, where the Discovery wintered last year. These men would seize the occasion of the opening of the frozen sea to push on to the pole. At the end of three years the party should be visited, and, if unsuccessful in accomplishing the object, should be revictualed and again left to their work. With a good, substantial building, such as could easily be carried on shipboard, they would be as comfortable and safe from atmospheric danger as the men of the Signal Service on the summit of Mount Washington. "A good supply of medicine," adds Captain Howgate, "a skillful surgeon, and such fresh provision as could be found by hunting-parties, would enable them to keep off scurvy, and to maintain as good a sanitary condition as the inhabitants of Godhaven in Greenland. Game was found in fair quantities by the Polaris party on the Greenland coast, and by those from the Alert and Discovery on the mainland to the west, especially in the vicinity of the last-named vessel, where fifty-four musk-oxen were killed during the season, with quantities of other and smaller game. A seam of good coal was also found by the Discovery's party, which would render the question of fuel a light one, and thus remove one of the greatest difficulties hitherto found by arctic voyagers. Let an expedition be organized to start in the spring of 1877, and I firmly believe that by 1880 the geography of the polar circle would be definitely settled, and that without loss of life."

Classification of the Races of Man.—The distinguished Italian ethnologist, Prof. Mantegazza, of Florence, in his introduction to Enrico Giglioli's narrative of a voyage round the Globe in the corvette Magenta, learnedly discusses the question of the classification of the races of man. His principal conclusions are that—1. Man is one of the most cosmopolitan and most variable of animals, and hence presents an infinite variety of races, sub-races, and peoples. 2. The number of races is indefinite; many races are extinct, others are now forming, still others will yet be produced. 3. The farther back we go in history, the larger is the number of races and sub-races, for in early times men less frequently moved away from their native localities and were more isolated from one another than now. 4. At the top and at the bottom of the human genealogical tree the branches and twigs approach one another, so that the most highly-cultured and the least developed races come into mutual contact. The negro developed into a Kaffre approximates to the European, and the European, degraded by cretinism or by hunger, to the Australian or the negro. 5. In general the lowest races are black or dark brown, the middle races somewhat less dark-skinned, and the highest white or nearly so. 6. In classifying the races of man we must, as far as possible, omit the question of their origin, for the investigation of this origin is the most fruitful source of ethnological errors.

The American Geographical Society.—The American Geographical Society was formally installed in its new quarters, No. 11 West Twenty-ninth Street, New York, November 28th. For many years this Society

had rooms in the Cooper Union Building, but from the beginning it has been the intention of the leading members to secure possession of a building large enough to receive their valuable collection and library. The new headquarters is a large four-story and basement brown-stone front house on Twenty-ninth Street, near Fifth Avenue. On the first floor is a spacious reception-room, extending the entire depth of the house; its walls are covered with maps and charts. One of the curiosities of this room is the large map of South America once used by Humboldt. On this floor is also the room of the president of the Society. The second floor is devoted to the library and the secretary's room. In the library are 20,000 volumes, classified according to countries. The third floor contains the collection of maps and atlases. On the fourth floor is the Council's room, and in the basement are the offices for the clerical force.

On the evening of November 29th a second reception was held by the Society, and a paper on a journey to the Spitzbergen Sea was read by A. H. v. d. Hoeck. The author took occasion to expatiate upon the value of arctic research, pointing out the important results thence to be derived for anthropology, zoölogy, geology and paleontology, physics, and meteorology. Manuel M. Pereira, minister resident of Costa Rica, read a short paper on the projected canal across the Isthmus of Darien.

Hygrometers.—An hygrometer is an instrument for measuring the moisture of the atmosphere. It is often useful for gauging the dryness of rooms. It may not be generally known how simply such an instrument may be constructed.

When water, by means of a moist rag (whose moisture may be kept up by contact with water in a saucer or teacup), is spread over the surface of the bulb of a thermometer, the mercury in the latter falls, generally several degrees. The reason is, that the water evaporates and cools the bulb. The evaporation which takes place is, of course, produced by the absorption of heat from surrounding objects, the bulb included. The thermometer is affected in proportion to the reduction of temperature caused by the evaporation. It is evident that just as much heat as is required to convert water into vapor, just so much cold (or deprivation of heat) will be required to convert the vapor back again into water. When vapor begins to condense into water the temperature is at what is called the dew-point. It is evident, therefore, that theoretically the dew-point is twice as far as the vapor-point below the normal temperature of the atmosphere. Experiments show that it is a little more; a constant quantity of $1\frac{2}{3}°$ Fahr. having to be added for heat lost and dissipated in the process.

These facts may be exemplified as follows: Hang two thermometers in a room of equable temperature, and suspend a third in a tin or glass vessel containing some tepid water. Wet the bulb of thermometer No. 2 as suggested above, and the evaporation will show the vapor-point. Pour ice-water gradually and slowly into the vessel containing No. 3, and mingle it well with the water already there until the whole becomes so cold that the exterior of the vessel begins to contract moisture. It is then at the dew-point, and the thermometer in the vessel will be found to have fallen twice as much as No. 2, and $1\frac{2}{3}°$ more.

No. 2 is a perfect hygrometer, as it shows the relative dampness of the atmosphere. When the latter is very dry, as in a room warmed by a hot-air furnace, evaporation takes place rapidly, and a large quantity of heat is abstracted from the bulb. When moist, as during a shower, very little evaporation takes place, and there is but a slight fall of the hygrometer. When the atmosphere is too dry the lungs suffer. It is in a wholesome condition when the hygrometer does not fall more than 7° Fahr. below the normal temperature. A hot-air furnace often sends it down 10° or 12° below.

The Studies of an Engineer.—Prof. Reynolds, of Owens College, Manchester, in an address on "Engineering as a Profession," proposes the following course of preparation for the student who aims to be an engineer: Up to the age of sixteen or seventeen he should devote himself to acquiring a "general education." Then he enters on his special course. In this he must learn something of science and something of art;

but his main object should be to learn how the one can be brought to bear upon the other. Mathematics and natural science are indispensable, but he must not expect to become a master of either. Only a comparatively small portion of these wide subjects can be usefully brought to bear on engineering, and to these he must restrict himself. The methods of applying these sciences to engineering problems constitute a large subject, and one that is necessary for him to study. Then there are those manual operations which are essential to bring his knowledge to a practical issue, and in which a long course of training is necessary to acquire the requisite skill, such as mechanical drawing, and the use of measuring and surveying instruments. To acquire a useful knowledge of these various branches will require three or at least two years. The student will then proceed with his practical training, which should include as great a range of work as possible. In this he will find the knowledge he has acquired of very great help; he will recognize much that he sees, and be able to judge of the most important things to which to direct his attention.

Absorption of Nitrogen by Plants.—The chemist Berthelot has submitted to the Paris Academy of Sciences the results of a new series of experiments which prove that, under the influence of atmospheric electricity, free nitrogen is absorbed by the proximate principles of plants. The apparatus used in these experiments consists of a system of tubes in which the organic substances come into contact either with pure nitrogen or with atmospheric air, the whole communicating with a source of electricity at a tension precisely the same as that of atmospheric electricity. Under these conditions pure nitrogen, or the nitrogen of the atmosphere, is invariably fixed by the organic matter employed, viz., wet filtering-paper or a solution of dextrine. The amount of nitrogen that is thus fixed is considerable. Thus these experiments bring to light a natural cause, hitherto overlooked, in considering the question of the fixation of nitrogen by vegetable tissues. It is now demonstrated that this fixation is brought about by the incessant action of the electricity of the atmosphere.

Development of Electricity by Light.—To determine experimentally the action of light in the development of electricity, Hankel took two bright strips of copper, one of which he fixed in a porous clay cell by means of a cork stopper. The cell was filled with water, and placed in a larger glass vessel containing the same water, in which was immersed the other strip, so that one of its surfaces was turned toward the source of light. The two strips were connected with the wire of a galvanometer. The glass with its contents was now placed in a black case having a slide, by means of which direct sunlight or colored light could be admitted to the outer strip of copper. The results were as follows: On access of free sunlight the illuminated strip was negative to the one in darkness, but only moderately so; behind a red glass the action was extremely small; behind yellow, a little stronger; behind green and dark blue successively, still stronger; behind dark violet it became less again.

The copper strips were now oxidized by moderate heating, and the following results were obtained: In free sunlight the illuminated strip was strongly negative; on darkening again, the deflection gradually disappeared; behind red glass the action was less; behind light-yellow glass the plate was first positive, then negative; on darkening, it first became still more negative, and then the action disappeared; behind dark-green glass the behavior was similar, but the first positive deflection was less; behind bright-blue, dark-blue, and violet glass, the plate was equally negative.

Strongly oxidized copper strips were next tested. In free sunlight the illuminated strip was first strongly positive, then weakly negative; on darkening, it was first strongly negative, then the action ceased. Behind red glass the plate was pretty strongly positive, but the deflection of the needle soon fell off considerably; behind bright-yellow glass the strip was very strongly positive, but very soon the action diminished; on darkening, a strong negative deflection occurred. Behind dark-green glass the plate was first weakly positive, and then negative; behind dark-blue glass the copper was also negative, and this change was more considerable than with free sunlight; behind violet glass, the action was similar.

The author describes also the behavior of copper in sulphate-of-copper solution, and the behavior of silver, tin, brass, zinc, platinum; which metals were examined in the same way.

American Vine-Stocks and the Phylloxera.—In a communication to the Paris Academy of Sciences, M. Boutin gives an account of researches made by him to ascertain the reason why some American vine-stocks resist the attacks of the *Phylloxera vastatrix*, while others succumb. The author has discovered in the resistant stocks a certain resinoid principle in proportion about a third greater than that in which it occurs in American non-resistant stocks, and in about double the proportion found in French stocks. M. Boutin considers it essential for resistance that the resinoid principle should occur in the proportion of 8 per cent. for the entire root, and 14 to 15 per cent. in the bark alone. He says that the incision made by the insect, while producing nodosities in the root, is cicatrized by the exudation of the resinous product, and this prevents the escape or loss of the nutritive sap of the plant. In non-resistant stocks, on the other hand, there is no cicatrization, as the resinoid principle is not in sufficient quantity to produce this effect.

Naturalists' Report of the British Arctic Expedition.—The results obtained by the naturalists attached to the British North-Polar Expedition may be briefly summed up as follows: The mammals found farthest north, on the shore of the great Polar Basin, were the arctic fox, wolf, ermine, polar hare, lemming, and musk-ox. Bird-life was present as far as the land extended, the outlying species being the snowy owl, snow-bunting, and ptarmigan. Of fishes few marine species were procured, but an interesting small salmonoid was found in fresh-water lakes up to about latitude 82° 35′. Insect-life was more abundant than could have been expected, and a goodly number of species were obtained. Over twenty species of phænogamic plants were discovered between latitudes 82° and 83°, and the cryptogamic flora was of course much more varied and abundant. The whole west coast of Smith's Sound, from Cape Isabella to Cape Union, was fully surveyed and mapped, and large collections made of both fossils and rock-specimens; while the sled-parties, which explored the shores of the Polar Basin both to east and west, brought back sufficient material to determine the geological character of the country. Silurian limestones, richly fossiliferous, were the prevailing rocks along Smith's Sound. From the shales and sandstones of this formation a beautiful series of leaf-impressions were collected, illustrating the characteristic flora of the epoch, and presenting a remarkable demonstration of the existence of a temperate climate within 500 miles of the present pole, at a comparatively recent geological time. Lastly, very interesting and suggestive observations were made on glaciation and on ice-action in general.

The Berlin Gorilla.—At the recent meeting of the German Association of Naturalists, Dr. Hermes, as we are informed by *Nature*, described some interesting characteristics of the young gorilla in the Berlin Aquarium. He nods and claps his hands to visitors; wakes up like a man and stretches himself. His keeper must always be beside him and eat with him; he eats what his keeper eats; they share dinner and supper; the keeper must remain by him till he goes to sleep, his sleep lasting eight hours. His easy life has increased his weight in a few months from thirty-one to thirty-seven pounds. For some weeks he had inflammation of the lungs, when his old friend Dr. Falkenstein was fetched, who treated him with quinine and Ems-water, which made him better. When Dr. Hermes left the gorilla on the previous Sunday, the latter showed the doctor his tongue, clapped his hands, and squeezed the hand of the doctor as an indication, the latter believed, of his recovery. For Pungu, as the gorilla is called, a large plate-glass palace has been erected in the aquarium in connection with the palm-house.

Lightning in a Telegraph-Office.—A telegraph-operator, in an office on the Boston and Providence Railroad, was lately killed by lightning. This is said to be the only case on record of an operator killed by lightning while in the office. Remarking upon this casualty, the *Telegraphic Journal* says that,

"so far from being a source of danger, the electric telegraph must be regarded rather as a cause of safety, as a network of lines spread over a country tends to prevent an accumulation of electricity at any particular point, by continually and silently discharging it to the earth. This is particularly the case in districts where every pole has an earth-wire fixed to it, running from the top to the bottom. That these wires effectually discharge a lightning-flash has been seen in cases where the wires have been terminated within a few inches of the top of the pole: a lightning-flash striking one of these destroyed the portion of pole above the wire, but at the point where the wire commenced all damage ceased."

NOTES.

Under the head of "Commercial Manias," we referred last month to the banking enterprise of a lady at Madrid. The *Economist* of December, 1876, reports further on the case, as follows: "The extraordinary banking at Madrid, by a lady who paid twenty per cent. interest monthly on deposits, has ended in a manner which has long been expected. She disappeared a few days back with a sum of three million and a half of francs ($700,000), out of five million and a half ($900,000) she had received from 6,700 depositors. The difference had been returned in interests."

Recent additions to the museum of the Buffalo Society of Natural Sciences embrace a small collection of European *Lepidoptera*, presented by Prof. Zeller, of Stettin; a few rare specimens from the Museum of Comparative Zoölogy, and a collection of California *Geometræ* from Prof. Behrens, of San Francisco; also a collection of butterflies and moths from Mr. John D. Shepard, taken on the Wahsatch Mountains, twenty-five miles south of Salt Lake City.

An association of ladies has been formed in Boston, entitled the Boston University Women's Educational Society, for the purpose of promoting the higher education of women. The Society proposes to aid needy students by gifts and loans, and also to found resident and traveling fellowships, to encourage original research, and in general to afford to young women all the educational facilities now accessible only to young men. A fund amounting to $40,000 has already been accumulated.

A small coleopterous insect (*Anthrenus scrophulariæ*) common in Europe, but hitherto unknown in the United States, has made its appearance in the neighborhood of Albany. The larva of this insect is a great destroyer of clothes, furs, natural-history collections, etc., and at Albany much damage has been done by it to carpets.

The Litchfield Astronomical Observatory, of Hamilton College, of which Prof. C. H. F. Peters has been for nearly twenty years the very efficient director, has lately been enlarged. Efforts are being made to retain the services of Prof. Porter as assistant astronomer.

Died, October 19th, at the age of fifty-four years, Carl Jelinek, for thirteen years director of the Vienna Central Institute for Meteorology and Magnetism. His papers on Austrian meteorology are held in very high esteem, and his "Introduction to Meteorological Observations" has reached the third edition.

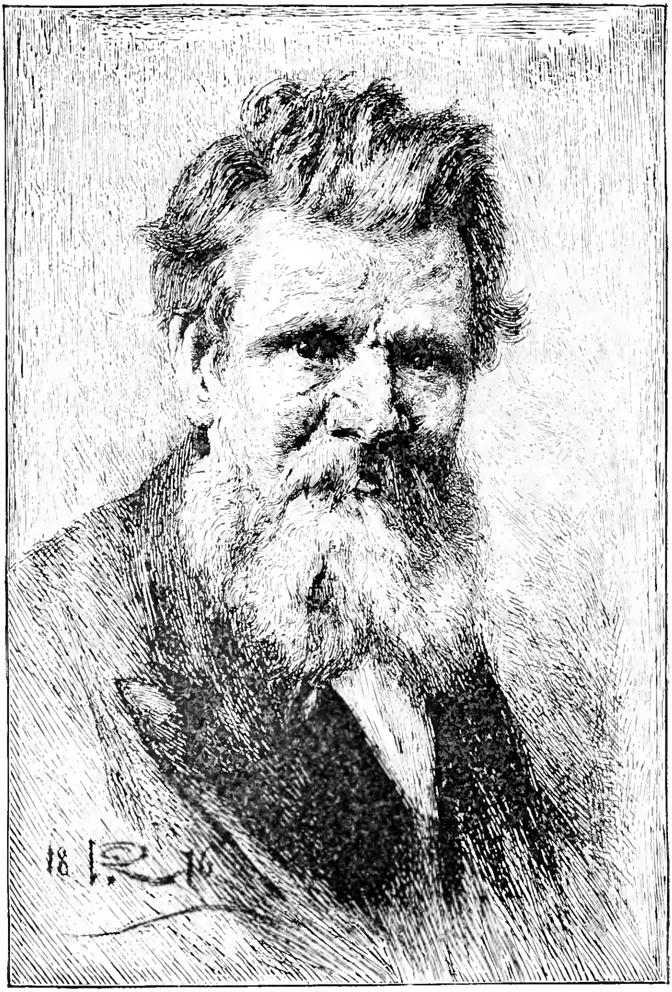
The *American Chemist* for September announces the discovery of a new element by Dr. George A. Koenig, of the University of Pennsylvania. From a mineral resembling schorlamite, occurring at Magnet Cove, Arkansas, he obtained, in the place of titanic acid, a *white oxide*, which differs from the former very materially, and he regards the existence in it of a new metal as highly probable.

The subscription for a monument to Liebig in Germany has reached the sum of 140,000 marks, and the lists are now closed. Giessen and Munich claim the statue each for itself. It has been decided that both towns shall have the same memorial, which will be cast in bronze, the sum collected being sufficient to cover the double expense.

Williams College will next summer send an exploring party to the Rocky Mountains, under the lead of Prof. Sanborn Tenney, Professor of Natural History. The party will consist of fifteen students, who, during the remainder of the college year, will receive special instruction to fit them for the performance of their respective duties.

The statue of Faraday, the commission for which was placed in the hands of the late sculptor Foley, and which was far advanced by him in the full-sized model at the time of his death, has been completed in marble by one of the disciples of the deceased artist, and is now awaiting arrangements for erection.

In an article on the scurvy which broke out among the sled-parties of the British Polar Expedition, the *Sanitary Record* says that never were the plainest results of past experience and the best-established rules of naval hygiene more recklessly and disastrously set at naught than in these sled-expeditions.



Thomas Edward

THE

POPULAR SCIENCE MONTHLY.

MARCH, 1877.

EDUCATION AS A SCIENCE.

BY ALEXANDER BAIN, LL. D.,
PROFESSOR IN THE UNIVERSITY OF ABERDEEN.

II.

The Retentive Faculty.

THIS is the faculty that most of all concerns us in the work of education. On it rests the possibility of mental growths or capabilities not given by Nature.

Every impression made upon us, if sufficient to awaken consciousness at the time, has a certain permanence; it can persist after the original ceases to work; and it can be restored afterward as an idea or remembered impression. The bursting out of a flame arouses our attention, gives a strong visible impression, and becomes an idea or deposit of memory. It is thought of afterward without being actually seen.

It is not often that one single occurrence leaves a permanent and recoverable idea; usually, we need several repetitions for the purpose. The process of fixing the impression occupies a certain length of time; either we must prolong the first shock, or renew it on several successive occasions. This is the first law of memory, Retention or Acquisition: "Practice makes perfect;" "exercise is the means of strengthening a faculty," etc. The good old rule of the schoolmaster is simply to make the pupil repeat, rehearse, or persist at a lesson until it is learned.

All improvement in the art of teaching consists in having regard to the various circumstances that facilitate acquirement, or lessen the number of repetitions for a given effect. Much is possible in the way of economizing the plastic power of the human system; and when we have pushed this economy to the utmost, we have made perfect the Art of Education in one leading department. It is thus necessary

that the consideration of all the known conditions that favor or impede the plastic growth of the system should be searching and minute.

Although some philosophers have taught that all minds are nearly equal in regard to facility of acquirement, a schoolmaster that would say so must be of the very rudest type. The inequality of different minds in imbibing lessons, under the very same circumstances, is a glaring fact; and is one of the obstacles encountered in teaching numbers together, that is, classes. It is a difficulty that needs a great deal of practical tact or management, and is not met by any educational theory.

The different kinds of acquirements vary in minor circumstances which are important to be noticed after exhausting the general or pervading conditions. The greatest contrast is between what belongs to intelligence, and what belongs to the feelings and the will. The more strictly intellectual department comprises Mechanical Art, Language, the Sensible World, the Sciences, Fine Art; and to each of these heads may attach specialties not hard to assign.

General Circumstances favoring Retentiveness.—1. The physical condition. This has been already touched upon, both in the review of physiology, and in the remarks on discrimination. It includes general health, vigor and freshness at the moment, together with the further indispensable proviso that the nutrition, instead of being drafted off to strengthen the mere physical functions, is allowed to run in good measure to the brain.

In the view of mental efficiency, the muscular system, the digestive system, and the various organic interests, are to be exercised up to the point that conduces to the maximum of general vigor in the system, and no further. They may be carried further in the interest of sensual enjoyment, but that is not now before us. Hence a man must exercise his muscles, must feed himself liberally and give time to digestion to do its work, must rest adequately—all for the greatest energy of the mind, and for the trying work of education in particular. Nor is it so very difficult, in the present state of physiological and medical knowledge, to assign the reasonable proportions in all these matters, for a given case.

Everything tends to show that, in the mere physical point of view, the making of impressions on the brain, although never remitted during all our waking moments, is exceedingly unequal at different times. We must be well aware that there are moments when we are incapable of receiving any lasting impressions, and there are moments when we are unusually susceptible. The difference is not one wholly resolvable into mere mental energy on the whole; we may have a considerable reserve of force for other mental acts, as the performance of routine offices, and not much for retaining new impressions; we are capable of reading, talking, writing, and for taking an interest in the exer

cises; we may indulge emotions, and carry out pursuits, and yet not be in a state for storing the memory, or amassing knowledge. Even the incidents that we take part in sometimes fail to be remembered beyond a very short time.

What, then, is there so very remarkable and unique in the physical support of the plastic property of the brain? What are the moments when it is at the plenitude of its efficiency? What are the things that especially nourish and conserve it?

Although there is still wanting a careful study of this whole subject, the patent facts appear to justify us in asserting that the plastic or retentive function is the very highest energy of the brain, the consummation of nervous activity. To drive home a new experience, to make an impression self-sustaining and recoverable, uses up (we are to suppose) more brain-force than any other kind of mental exercise. The moments of susceptibility to the storing up of knowledge, the engraving of habits and acquisitions, are thus the moments of the maximum of unexpended force. The circumstances need to be such as to prepare the way for the highest manifestation of cerebral energy; including the perfect freshness of the system, and the absence of everything that would speedily impair it.

To illustrate this position, I may refer to the kind of mental work that appears to be second in its demand on the energy of the brain. The exercise of mental constructiveness—the solving of new problems, the applying of rules to new cases, the intellectual labor of the more arduous professions, as the law, where a certain amount of novelty attends every case that occurs—demands no little mental strain, and is easy according to the brain-vigor of the moment. Still, these are exercises that can be performed with lower degrees of power; we are capable of such professional work in moments when our memory would not take in new and lasting impressions. In old age, when we cease to be educable in any fresh endowment, we can still perform these constructive exercises; we can grapple with new questions, invent new arguments and illustrations, decide what should be done in original emergencies.

The constructive energy has all degrees, from the highest flights of invention and imagination down to the point where construction shades off into literal repetition of what has formerly been done. The preacher in composing a fresh discourse puts forth more or less of constructiveness; in repeating prayers and formularies, in reading from book, there is only reminiscence. This is the third and least exigent form of mental energy; it is possible in the very lowest states of cerebral vigor. When acquisition is fruitless, construction is possible; when a slight departure from the old routine passes the might of the intelligence, literal reminiscence may operate.

Another mode of mental energy that we are equal to, when the freshness of our susceptibility to new growths has gone off, is search-

ing and noting. This needs a certain strain of attention; it is not possible in the very lowest tide of the nervous flow; but it may be carried on with all but the smallest degrees of brain-power. When the scholar or the man of science ceases to trust his memory implicitly for retaining new facts that occur in his reading, observation, or reflection, he can still keep a watch for them, and enter them in his notes. So in the hours of the day when memory is less to be trusted, useful study may still be maintained by the help of the memorandum and the note-book.

The indulgence of the emotions (when not violent or excessive) is about the least expensive of our mental exercises, and may go on when we are unfit for any of the higher intellectual moods, least of all for the crowning work of storing up new knowledge or new aptitudes. There are degrees here also; but, speaking generally, to love or to hate, to dominate or to worship, although impossible in the lowest depths of debility, are within the scope of the inferior grades of nervous power.

From this estimate of comparative outlay, we may judge what are the times and seasons and circumstances most favorable to acquirement. It may be assumed that in the early part of the day the total energy of the system is at its height, and that toward evening it flags; hence morning is the season of improvement. For two or three hours after the first meal, the strength is probably at the highest; total remission for another hour or two, and a second meal (with physical exercise when the labor has been sedentary), prepares for a second display of vigor, although presumably not equal to the first; when the edge of this is worn off, there may, after a pause, be another bout of application, but far inferior in result to the first or even to the second. No severe strain should be attempted in this last stage; not much stress should be placed on the available plasticity of the system, although the constructive and routine efforts may still be kept up.

The regular course of the day may be interfered with by exceptional circumstances, but these only confirm the rule. If we have lain idle or inactive for the early hours, we may of course be fresher in the evening, but the late application will not make up for the loss of the early hours; the nervous energy will gradually subside as the day advances, however little exertion we may make. Again, we may at any time determine an outburst of nervous energy by persistent exercise and by stimulation, which draws blood to the brain, without regard to circumstances and seasons, but this is wasteful in itself and disturbing to the healthy functions.

As a general rule, the system is at its greatest vigor in the cold season of the year; and most work is done in winter. Summer studies are comparatively unproductive.

The review of the varying plasticity in the different stages of life might be conducted on the same plan of estimating the collective

forces of the system, and the share of these available for brain-work, but other circumstances have to be taken into the account, and I do not enter upon the question here.

There are many details in the economy of the plastic power that have a physical as well as a mental aspect. Such are those relating to the strain and remission of the attention, to the pauses and alternations during the times of drill, to the moderating of the nervous excitement, and other matters. These should all find a place under the head of the Retentive function. It is expedient now to take up the consideration of the subject from the purely mental side.

2. The one circumstance that sums up all the mental aids to plasticity is CONCENTRATION. A certain expenditure of nervous power is involved in every adhesion, every act of impressing the memory, every communicated bias; and the more the better. This supposes, however, that we should withdraw the forces, for the time, from every other competing exercise; and, especially, that we should redeem all wasting expenditure for the purpose in view.

It is requisite, therefore, that the circumstances leading to the concentration of the mind should be well understood. We assume that there is power available for the occasion, and we seek to turn it into the proper channel. Now, there is no doubt that the will is the chief intervening influence, and the chief stimulants of the will are, as we know, pleasure and pain. This is the rough view of the case. A little more precision is attainable through our psychological knowledge.

And first, the will itself as an operating or directing power, that is to say, the moving of the organs in a given way under a motive, is a growth or culture; it is very imperfect at first, and improves by usage. A child of twelve months cannot by any inducement be prompted readily to clap its hands, to point with its forefinger, to touch the tip of its nose, to move its left shoulder forward. The most elementary acts of the will, the alphabet of all the higher acquisitions, have first to be learned in a way of their own; and until they have attained a sufficient advancement, so as to be amenable to the spur of a motive, the teacher has nothing to go upon.

I have elsewhere described this early process, as I conceive it, in giving an account of the development of the will. In the practice of education, it is a matter of importance as showing at what time mechanical instruction is possible, and what impedes its progress at the outset, notwithstanding the abundance of plasticity in the brain itself. The disciplining of the organs to follow directions would seem to be the proper province of the infant school.

Coming now to the influences of concentration, we assign the first place to intrinsic charm, or *pleasure in the act* itself. The law of the will, in its side of greatest potency, is that pleasure sustains the movement that brings it. The whole force of the mind at the moment

goes with the pleasure-giving exercise. The harvest of immediate pleasure stimulates our most intense exertions, if exertion serves to prolong the blessing. So it is with the deepening of an impression, the confirming of a bent or bias, the associating of a couple or a sequence of acts; a coinciding burst of joy awakens the attention, and thus leads to an enduring stamp on the mental framework.

The ingraining efficiency of the pleasurable motive requires not only that we should not be carried off into an accustomed routine of voluntary activities, such as to give to the forces another direction, as when we pace to and fro in a flower-garden; but also that the pleasure should not be intense or tumultuous. The law of the mutual exclusion of great pleasure and great intellectual exertion forbids the employment of too much excitement of any kind, when we aim at the most exacting of all mental results—the forming of new adhesive growths. A gentle pleasure that for the time contents us, there being no great temptation at hand, is the best foster-mother of our efforts at learning. Still better, if it be a growing pleasure; a small beginning, with steady increase, never too absorbing, is the best of all stimulants to mental power. In order to have a yet wider compass of stimulation, without objectionable extremes, we might begin on the negative side, that is, in pain or privation, to be gradually remitted in the course of the studious exercise, giving place at last to the exhilaration of a waxing pleasure. All the great teachers, from Socrates downward, seem to recognize the necessity of putting the learner into a state of pain to begin with; a fact that we are by no means to exult over, although we may have to admit the stern truth that is in it. The influence of pain, however, takes a wider range than here supposed, as will be seen under our next head.

A moderate exhilaration and cheerfulness, growing out of the act of learning itself, is certainly the most genial, the most effectual means of cementing the unions that we desire to form in the mind. This is meant when we speak of the learner having a taste for his pursuit, having the *heart* in it, learning *con amore*. The fact is perfectly well known; the error, in connection with it, lies in dictating or enjoining this state of mind on everybody in every situation, as if it could be commanded by a wish, or as if it were not itself an expensive endowment. The brain cannot yield an exceptional pleasure without charging for it.

Next to pleasure in the actual, as a concentrating motive, is pleasure in *prospect*, as in learning what is to bring us some future gratification. The stimulus has the inferiority attaching to the idea of pleasure as compared with the reality. Still it may be of various degrees, and may rise to a considerable pitch of force. Parents often reward their children with coins for success in their lessons; the conception of the pleasure in this case is nearly equal to a present tremor of sense-delight. On the other hand, the promises of fortune and

distinction, after a long interval of years, have seldom much influence in concentrating the mind toward a particular study.

Let us now view the operation of pain. By the law of the will, pain repels us from the thing that causes it. A painful study repels us, just as an agreeable one attracts and detains us. The only way that pain can operate is when it is attached to neglect, or to the want of mental concentration in a given subject; we then find pleasure, by comparison, in sticking to our task. This is the theory of punishing the want of application. It is in every way inferior to the other motives; and this inferiority should be always kept in view in employing it, as every teacher often must with the generality of scholars. Pain is a waste of brain-power; while the work of the learner needs the very highest form of this power. Punishment works at a heavy percentage of deduction, which is still greater as it passes into the well-defined form of terror. Every one has experienced cases where severity has rendered a pupil utterly incapable of the work prescribed.

Discarding all *a priori* theories as to whether the human mind can be led on to study by an ingenious system of pleasurable attractions, we are safe in affirming that if the physical conditions are properly regarded, if the work is within the compass of the pupil's faculties, and if a fair amount of assistance is rendered in the way of intelligible direction, although some sort of pain will frequently be necessary, it ought not to be so great as to damp the spirits and waste the plastic energy.

The line of remark is exactly the same for pain in prospect, with allowance for the difference between reality and the idea. It is well when prospective pain has the power of a motive, because the future bad consequences of neglect are so various and so considerable as to save the resort to any other. But since the young mind in general is weak in the sense of futurity, whether for good or for evil, only very near, very intelligible, and very certain pains, can take the place of presently-acting deterrents.

In the study of the human mind, we need, for many purposes, to draw a subtile distinction between feeling as pleasure or pain, and feeling as excitement not necessarily pleasurable or painful. This subtilty cannot be dispensed with in our present subject. There is a form of mental concentration that is properly termed excitement, and is not properly termed pleasurable or painful excitement. A loud or sudden shock, a rapid whirling movement, stirs, wakens, or excites us; it may also give us pleasure or pain, but it may be perfectly neutral; and even when there is pleasure or pain, there is an influence apart from what would belong to pleasure or pain, as such. A state of excitement seizes hold of the mind for the time being and shuts out other mental occupations; we are engrossed with the subject that brought on the state, and are not amenable to extraneous influences, until that has subsided. Hence, excitement is preëminently a means

of making an impression, of stamping an idea in the mind; it is strictly an intellectual stimulus. There is still the proviso (under the general law of incompatibility of the two opposite moods) that the excitement must not be violent and wasting. In well-understood moderation, excitement is identical with attention, mental engrossment, the concentration of the forces upon the plastic or cementing operation, the rendering permanent as a recollection what lies in the focus of the blaze. Excitement, so defined, is worthless as an end, but is valuable as a means; and that means is the furtherance of our mental improvement by driving home some useful concatenation of ideas.

Another subtilty remains—a distinction within a distinction. After contrasting feeling as excitement with feeling as pleasure or pain, we must separate the useful from the useless or even pernicious modes of excitement. The useful excitement is what is narrowed and confined to the subject to be impressed; the useless, and worse than useless, excitement is what spreads far and wide, and embraces nothing in particular. It is easy to get up the last species of excitement—the vague, scattered, and tumultuous mode—but this is not of avail for any set purpose; it may be counted rather as a distracting agency than as a means of calling forth and concentrating the attention upon an exercise.

The true excitement for the purpose in view is what grows out of the very subject itself, surrounding and adhering to that subject. Now, for this kind of excitement, the recipe is continuous application of the mind in perfect surrounding stillness. Restrain all other solicitation of the senses; keep the attention upon the one act to be learned; and, by the law of nervous and mental persistence, the currents of the brain will become gradually stronger and stronger, until they have reached the point when they do no more good for the time. This is the ideal of concentration by neutral excitement.

The enemy of such happy neutrality is pleasure from without; and the youthful mind cannot resist the distraction of a present pleasure, or even the scent of a far-off pleasure. The schoolroom is purposely screened off from the view of what is going on outside; while all internal incidents that hold out pleasurable diversion are carefully restrained, at least during the crisis of a difficult lesson. A touch of pain, or apprehension, if *only slight*, is not unfavorable to the concentration.

A very important observation remains, namely, that relationship of retention to discrimination which was stated in introducing the function of discrimination. The consideration of this relationship illustrates with still greater point the true character of the excitement that concentrates and does not distract nor dissipate the energies. The moment of a delicate discrimination is the moment when the intellectual force is dominant; emotion spurns nice distinctions,

and incapacitates the mind for feeling them. The quiescence and stillness of the emotions enables the mind to give its full energies to the intellectual processes generally; and of these, the fundamental is perception of difference. Now, the more mental force we can throw into the act of noting a difference, the better is that difference felt, and *the better it is impressed.* The same act that favors discrimination favors retention. The two cannot be kept separate. No law of the intellect appears to be more certain than the law that connects our discriminating power with our retentive power. In whatever class of subjects our discrimination is great—colors, forms, tunes, tastes—in that class our retention is great. Whenever the attention can be concentrated on a subject in such a way as to make us feel all its delicate lineaments, which is another way of stating the sense of differences, through that very circumstance a great impression is made on the memory; there is no more favorable moment for engraving a recollection.

The perfection of neutral excitement, therefore, is typified by the intense rousing of the forces in an act or a series of acts of discrimination. If by any means we can succeed in this, we are sure that the other intellectual consequences will follow. It is a rare and difficult attainment in volatile years; the conditions, positive and negative, for its highest consummation cannot readily be commanded. Yet we should clearly comprehend what these conditions are; and the foregoing attempt has been made to seize and embody them.

Pleasure and pain, besides acting in their own character—that is, directing the voluntary actions, have a power as mere excitement, or as wakening up the mental blaze, during which all mental acts, including the impressing of the memory, are more effective. The distinction must still be drawn between concentrated and diffused excitement, between excitement *in*, and excitement *away from*, the work to be done. Pleasure is the most favorable adjunct, if not too great. Pain is the more stimulating or exciting; under a painful smart the forces are very rapidly quickened for all purposes, until we reach the point of wasteful dissipation. This brings us round again to the Socratic position, the preparing of the learner's mind by the torpedo or the gad-fly.

The full compass of the operation of the painful stimulant is well shown in some of our most familiar experiences as learners. In committing a lesson to memory, we con it a number of times by the book: we then try without the book. We fail utterly, and are slightly pained by the failure. We go back to the book, and try once more without it. We still fail, but strain the memory to recover the lost trains. The pains of failure and the act of straining stimulate the forces; the attention is aroused seriously and energetically. The next reference to the book finds us far more receptive of the impression to be made; the weak links are now reënforced with

avidity, and the next trial shows the value of the discipline that has been undergone.

One remark more will close the view of the conditions of plasticity. It is, that discrimination and retentiveness have a common support in rapidity and sharpness of transition. A sharp and sudden change is commonly said to make a strong *impression:* the fact implied concerns discrimination and retention alike. Vague, shadowy, ill-defined boundaries fail to be discriminated, and the subjects of them are not remembered. The educator finds great scope for his art in this consideration also.

FORMATION OF RAINDROPS AND HAILSTONES.[1]

WHEN the particles of water or ice which constitute a cloud or fog are all of the same size, and the air in which they are sustained is at rest or is moving uniformly in one direction, then these particles can have no motion relatively to each other. The weight of the particles will cause them to descend through the air with velocities which depend on their diameters, and, since they are all of the same size, they will all move with the same velocity.

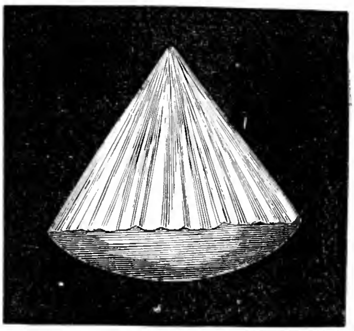


FIG. 1.—PERFECT HAILSTONE.

Under these circumstances, therefore, the particles will not traverse the spaces which separate them, and there can be no aggregation so as to form raindrops or hailstones.

If, however, from circumstances to be presently considered, some of the particles of the cloud or fog attain a larger size than others, these will descend faster than the others, and will consequently overtake those immediately beneath them; with these they may combine

[1] Abstract of paper "On the Manner in which Raindrops and Hailstones are formed," by Prof. Osborne Reynolds, M. A., read at the Literary and Philosophical Society, Manchester.

so as to form still larger particles which will move with greater velocity, and more quickly overtaking the particles in front of them will add to their size at an increasing rate.

Under such circumstances, therefore, the cloud would be converted into rain or hail according as the particles were water or ice.

The size of the drops from such a cloud would depend simply on the quantity of water suspended in the space swept through by the drop in its descent, that is to say, on the density and thickness of the cloud below the point from which the drops started.

The author's object is to suggest that this is the actual way in which raindrops and hailstones are formed. He was first led to this conclusion from observing closely the structure of ordinary hailstones. Although to the casual observer hailstones may appear to have no particular shape except that of more or less imperfect spheres, on closer inspection they are seen all to partake more or less of a conical

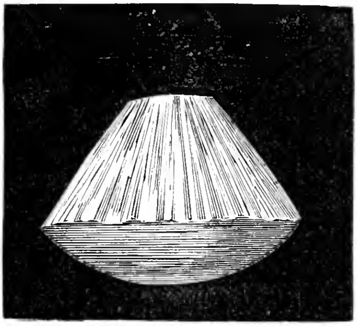


FIG. 2.—BROKEN HAILSTONE.

form with a rounded base like the sector of a sphere. In texture they have the appearance of an aggregation of minute particles of ice fitting closely together, but without any crystallization such as that seen in the snow-flake, although the surface of the cone is striated, the striæ radiating from the vertex. Such a form and texture as this is exactly what would result if the stones were formed in the manner described above. When a particle which ultimately formed the vertex of the cone started on its downward descent and encountered other particles on its lower face, they would adhere to it, however slightly. The mass, therefore, would grow in thickness downward; and as some of the particles would strike the face so close to the edge that they would overhang, the lower face would continually grow broader, and a conical form be given to the mass above.

When found on the ground the hailstones are generally imperfect; and besides such bruises as may be accounted for by the fall, many of them appear to have been imperfect before reaching the ground. Such deformities, however, may be easily accounted for. The larger stones fall faster than those which are smaller, and consequently may

overtake them in their descent; and then the smaller stones will stick to the larger and at once deform them. But besides the deformation caused by the presence of the smaller stone, the effect of the impact may be to impart a rotary motion to the stone, so that now it will no longer continue to grow in the same manner as before. Hence we have causes for almost any irregularities of form in the ordinary hailstone.

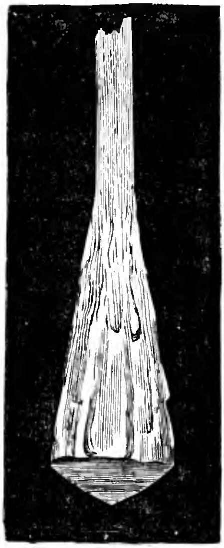


Fig. 3.—Imitation in Plaster of Paris.

It appears, from the numerous accounts which have been published, that occasionally hailstones are found whose form is altogether different from that described above. These, however, are exceptional, and, to whatever causes they may owe their peculiarities, these causes cannot affect the stones to which reference is here made.

Again, on careful examination, it is seen that the ordinary hailstones are denser and firmer toward their bases or spherical sides than near the vertex of the cone, which latter often appears to have broken off in the descent. This, also, is exactly what would result from the manner of formation described above. When the particle first starts it will be moving slowly, and the force with which the particles impinge upon it will be slight, and consequently its texture loose; as, however, it grows in size and its velocity increases, it will strike the particles it overtakes with greater force and so drive them into a more compact mass. If the velocity were sufficient, the particles would strike with sufficient force to adhere as solid ice, and this appears to be the case when the stones become large, as large as a walnut, for instance.

An idea of the effect of the suspended particles, on being overtaken

by the stone, may be formed from the action of the particles of sand in Mr. Tilghman's sand-blast, used for cutting glass. The two cases are essentially the same, the only difference being that the hailstone is moving through the air, whereas, in the case of the sand-blast, the object which corresponds to the stone is fixed, and the sand is blown against it.

By this sand-blast the finest particles of sand are made to indent the hardest material, such as quartz or hard steel; so that the actual intensity of the pressure between the surface of the particles of sand and that of the object they strike must be enormous. And yet the velocity of the blast is not so much greater than that at which a good-sized hailstone descends. It is easy to conceive, therefore, that the force of the impact of the suspended particles of ice, if not much below the temperature of freezing, on a large hailstone, would drive them together so as to form solid ice. For the effect of squeezing two particles of ice together is to cause them to thaw at the surface of contact, and as soon as the pressure is relieved they freeze again, and hence their adhesion.

It is then shown that hailstones, such as those described, can neither be formed by the freezing of raindrops, nor by the condensation of vapor on a nucleus of ice; and that it is impossible that the particles of ice can have been drawn together by electrical attraction

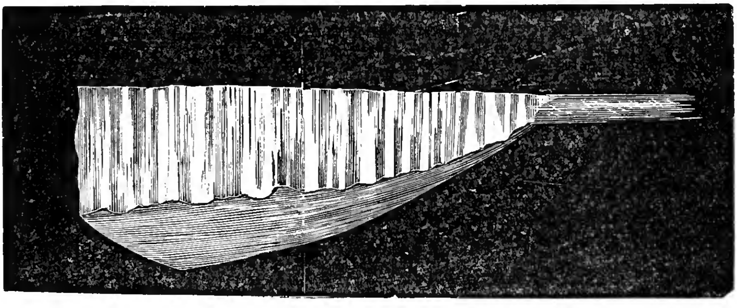


Fig. 4.—Imitation in Plaster of Paris.

—their conical shape, and the increase in their density toward their thicker sides, clearly showing that the particles have aggregated from one direction, and with an increasing force as the size of the stone has increased.

The possibility of making artificial stones is thus considered: If a stream of frozen fog were driven against any small object, then the frozen particles should accumulate on the object in a mass resembling a hailstone. Not seeing his way to obtain such a stream of frozen fog, the author thought it might be worth while to try the effect of blowing very finely-powdered plaster of Paris. He therefore introduced a stream of this material into a jet of steam, issuing freely into

the air (which he hoped would moisten the powdered plaster sufficiently to cause it to set firmly into whatever form it collected). The jet was directed against a splinter of wood.

In this way masses of plaster very closely resembling hailstones were obtained. They were all more or less conical, with their bases facing the jet. But, as might be expected, the angles of the cones were all smaller than those of the hailstones. Two of these figures are shown in the sketches annexed.

The striæ were strongly marked, and exactly resembled those of the hailstone. The bases also were rounded. They were somewhat steeper than those of the hailstone; but this was clearly due to the want of sufficient cohesive power on the part of the plaster. It was not sufficiently wet. Owing to this cause also it was not possible to preserve the lumps when they were formed, as the least shake caused them to tumble in pieces.

Similar masses were also obtained by blowing the vapor of naphthaline, but these were also very fragile. Whereupon it is remarked: At ordinary temperatures the powdered naphthaline does not adhere like ice when pressed into a lump. No doubt at very low temperatures ice would behave in the same way, that is to say, the particles would not adhere from the force of impact. Hence it would seem probable that, for hailstones to be formed, the temperature of the cloud must not be much below the freezing-point.

That the effect of the temperature of the cloud exercises great influence on the character of the hailstones cannot be doubted. And if, as has been suggested by M. L. Dufour, the particles will sometimes remain fluid, even when the temperature is as low as 0° Fahr., it is clear that, as they are swept up by a falling stone, they may freeze into homogeneous ice either in a laminated or crystalline form.

The author then proceeds to show that raindrops are probably formed in the same way as hailstones; that, although the raindrops have no structural peculiarities like the hailstones, the aggregation of the particles of water by the descent of the drop through the cloud is the only explanation which will account for them. He shows that, as Mr. Baxendell had previously pointed out, the amount of vapor which a cold drop could condense before it becomes as warm as the vapor would be inappreciable when compared with the size of the drop; and since, in order that there might be condensation, the air must be warmer than the drop, the drop could not part with its heat to the air. He also shows that during the time of descent of a large drop the heat lost by radiation would not account for the condensation of sufficient vapor to make any appreciable difference in the size of the drop. Whereas, if we suppose all the vapor which a body of saturated air at 60° Fahr. would contain over and above what it would contain at 32° to be changed into a fog or cloud, then if a particle, after commencing to descend, aggregated to itself all the water suspended

in the volume of air through which it swept, the diameter of the drop after passing through 2,000 feet would be more than an eighth of an inch, and after passing through 4,000 feet a quarter of an inch, and so on. So that, in passing through 8,000 feet of such cloud, it would acquire a diameter of half an inch.

The fact that raindrops never attain the size of large hailstones is explained as being due to the mobility in the case of large drops of the surface tension of the water, by which alone the drop retains its form, to withstand the disturbing force of the air rushing past; when the drop reaches a certain size, therefore, it is blown in pieces like the water from a fountain.

The origin of stones and drops is then discussed—why some of the particles in a cloud should be larger than the others, as it is necessary for them to be in order that they may commence a more rapid descent. A cloud does not always rain; and hence it would seem that in their normal condition the particles of a cloud are all of the same size and have no internal motion, and that the variation of size is due to some irregularity or disturbance in the cloud.

Such irregularity would result when a cloud is cooling by radiation from its upper surface. The particles on the top of the cloud being more exposed would radiate faster than those below them, and hence they would condense more vapor and grow more rapidly in size. They would therefore descend and leave other particles to form the top of the cloud. In this way we should have in embryo a continuous succession of drops.

Eddies in the cloud also form another possible cause of the origin of drops and stones.—*Nature.*

ON THE STUDY OF BIOLOGY.[1]

BY PROFESSOR T. H. HUXLEY.

IT is my duty to-night to speak about the study of biology, and while it may be that there are many among you who are quite familiar with that study, yet, as a lecturer of some standing, it would, I know by experience, be very bad policy on my part to suppose such to be extensively the case. On the contrary, I must imagine that there are many of you who would like to know what biology is; that there will be others who have that amount of information, but would nevertheless gladly learn why it should be worth their while to study biology; and yet others, again, to whom these two points are clear, but who desire to learn how they had best study it, and, finally, when

[1] A lecture by Prof. Huxley, delivered at the South Kensington Museum, on Saturday, December 16, 1876.

they had best study it; and I shall address myself to the endeavor to give you some answer to these four questions—what biology is; why it should be studied; how it should be studied; and when it should be studied.

In the first place, in respect to what biology is, there are, I believe, some persons who imagine that the term "biology" is simply a newfangled denomination, a neologism, in short, for what used to be known under the title of "natural history;" but I shall try to show you, on the contrary, that the word is the expression of the growth of science during the last two hundred years, and came into existence half a century ago.

At the revival of learning, knowledge was divided into two kinds—the knowledge of Nature, and the knowledge of man; for it was the current idea then (and a great deal of that ancient conception still remains) that there was a sort of essential antithesis, not to say antagonism, between Nature and man; and that the two had not very much to do with one another, except that the one was oftentimes exceedingly troublesome to the other. Though it is one of the salient merits of our great philosophers of the seventeenth century that they recognize but one scientific method, applicable alike to man and to Nature, we find this notion of the existence of a broad distinction between Nature and man in the writings of Bacon and Hobbes of Malmesbury; and I have brought with me that famous work which is now so little known, greatly as it deserves to be studied, "The Leviathan," in order that I may put to you, in the wonderfully terse and clear language of Thomas Hobbes, what was his view of the matter. He says:

"The register of knowledge of fact is called history. Whereof there be two sorts: one called natural history; which is the history of such facts or effects of Nature as have no dependence on man's will; such as are the histories of metals, plants, animals, regions, and the like. The other is civil history; which is the history of the voluntary actions of men in commonwealths."

So that all history of fact was divided into these two great groups of natural and of civil history. The Royal Society was in course of foundation about the time that Hobbes was writing this book, which was published in 1651, and that Society is termed a "Society for the Advancement of Natural Knowledge," which is nearly the same thing as a "Society for the Advancement of Natural History." As time went on, and the various branches of human knowledge became more distinctly developed and separated from one another, it was found that some were much more susceptible of precise mathematical treatment than others. The publication of the "Principia" of Newton, which probably gave a greater stimulus to physical science than any work ever published before, or which is likely to be published hereafter, showed that precise mathematical methods were applicable to

those branches of science, such as astronomy, and what we now call physics, which occupy a very large portion of the domain of what the older writers understood by natural history. And inasmuch as the partly deductive and partly experimental methods of treatment, to which Newton and others subjected these branches of human knowledge, showed that the phenomena of Nature which belonged to them were susceptible of explanation, and thereby came within the reach of what was called "philosophy" in those days, so much of this kind of knowledge as was not included under astronomy came to be spoken of as "natural philosophy"—a term which Bacon had employed in a much wider sense. Time went on, and yet other branches of science developed themselves. Chemistry took a definite shape, and as all these sciences, such as astronomy, natural philosophy, and chemistry, were susceptible either of mathematical treatment or of experimental treatment, or of both, a great distinction was drawn between the experimental branches of what had previously been called natural history and the observational branches—those in which experiment was (or appeared to be) of doubtful use, and where, at that time, mathematical methods were inapplicable. Under these circumstances the old name of "natural history" stuck by the residuum, by those phenomena which were not, at that time, susceptible of mathematical or experimental treatment; that is to say, those phenomena of Nature which come now under the general heads of physical geography, geology, mineralogy, the history of plants, and the history of animals. It was in this sense that the term was understood by the great writers of the middle of the last century—Buffon and Linnæus—by Buffon in his great work, the "Histoire Naturelle Générale," and by Linnæus in his splendid achievement, the "Systema Naturæ." The subjects they deal with are spoken of as "natural history," and they called themselves, and were called, naturalists. But you will observe that this was not the original meaning of these terms; but that they had, by this time, acquired a signification widely different from that which they possessed primitively.

The sense in which "natural history" was used at the time I am now speaking of has, to a certain extent, endured to the present day. There are now in existence, in some of our northern universities, chairs of Civil and Natural History, in which the term "natural history" is used to indicate exactly what Hobbes and Bacon meant by that term. There are others in which the unhappy incumbent of the chair of Natural History is, or was, still supposed to cover the whole ground of geology and mineralogy, zoölogy, perhaps even botany, in his lectures. But as science made the marvelous progress which it did make at the end of the last and the beginning of the present century, thinking men began to discern that under this title of "natural history" there were included very heterogeneous constituents—that, for example, geology and mineralogy were, in many respects, very

different from botany and zoölogy; that a man might obtain an extensive knowledge of the structure and functions of plants and animals, without having need to enter upon the study of geology and mineralogy, and *vice versa;* and, further, as knowledge advanced, it became clear that there was a great analogy, a very close alliance, between those two sciences of botany and zoölogy which deal with living beings, while they are much more widely separated from all other studies. It is due to Buffon to remark that he clearly recognized this great fact. He says: "Ces deux genres d'êtres organisés (les animaux et les végétaux) ont beaucoup plus de propriétés communes que de différences réelles." Therefore it is not wonderful that at the beginning of the present century, and oddly enough in two different countries, and, so far as I know, without any intercommunication between the respective writers, two famous men clearly conceived the notion of uniting the whole of the sciences which deal with living matter into one whole, and of dealing with them as one discipline. In fact, I may say there were three men to whom this idea occurred contemporaneously, although there were but two who carried it into effect, and only one who worked it out completely. The persons to whom I refer were the eminent physiologist Bichat,[1] the great naturalist Lamarck, in France; and a distinguished German, Treviranus. Bichat assumed the existence of a special group of "physiological" sciences. Lamarck, in a work published in 1801,[2] for the first time made use of the name "biologie," from the two Greek words which signify a *discourse upon life and living things.* About the same time it occurred to Treviranus that all those sciences which deal with living matter are essentially and fundamentally one, and ought to be treated as a whole, and in the year 1802 he published the first volume of what he also called "Biologie." Treviranus's great merit consists in this, that he worked out his idea, and that he published the very remarkable book to which I refer, which consists of six volumes, and which occupied him for twenty years—from 1802 to 1822.

That is the origin of the term "biology," and that is how it has come about that all clear thinkers and lovers of consistent nomenclature have substituted for the old confusing name of "natural history," which has conveyed so many meanings, the term "biology" to denote the whole of the sciences which deal with living things, whether they be animals or whether they be plants. Some little time ago—in the course of this year, I think—I was favored by a learned classic, Dr. Field, of Norwich, with a disquisition, in which he endeavored to prove that from a philological point of view neither Treviranus nor Lamarck had any right to coin this new word "biology" for his

[1] *See* the distinction between the "sciences physiques" and the "sciences physiologiques" in the "Anatomie Générale," 1801.

[2] "Hydrogéologie," an. x. (1801).

purpose; that, in fact, the Greek word "bios" had relation only to human life and human affairs, and that a different word was employed when they wished to speak of the life of animals and plants. So Dr. Field tells us we are all wrong in using the term biology, and that we ought to employ another—only, unluckily, he is not quite sure about the propriety of that which he proposes as a substitute. It is a somewhat hard one—zoötocology. I am sorry we are wrong, because we are likely to continue so. In these matters we must have some sort of "statute of limitations." When a name has been employed for half a century, persons of authority [1] have been using it, and its sense has become well understood, I am afraid that people will go on using it, whatever the weight of philological objection.

Now that we have arrived at the origin of this word "biology," the next point to consider is, What ground does it cover? I have said that in its strict technical sense it covers all the phenomena that are exhibited by living things, as distinguished from those which are not living; but while that is all very well so long as we confine ourselves to the lower animals and to plants, it lands us in a very considerable difficulty when we reach the higher forms of living things. For, whatever view we may entertain about the nature of man, one thing is perfectly certain, that he is a living creature. Hence, if our definition is to be interpreted strictly, we must include man and all his ways and works under the head of biology; in which case we should find that psychology, politics, and political economy, would all be absorbed into the province of biology. In fact, civil history would be merged in natural history. In strict logic it may be hard to object to this course, because no one can doubt that the rudiments and outlines of our own mental phenomena are traceable among the lower animals. They have their economy and their polity; and if, as is always admitted, the polity of bees and the commonwealth of wolves fall within the purview of the biologist proper, it becomes hard to say why we should not include therein human affairs, which in so many cases resemble those of bees in zealous getting, and are not without a certain parity in the proceedings of wolves. The real fact is, that we biologists are a self-sacrificing people; and inasmuch as, on a moderate estimate, there are about a quarter of a million different species of animals and plants to know about already, we feel that we have more than sufficient territory. There has been a sort of practical convention by which we give up to a different branch of science what Bacon and Hobbes would have called "civil history." That branch of science has constituted itself under the head of sociology. I may use phraseology which at present will be well understood, and say that we have allowed that province of biology to become autono-

[1] "The term *biology*, which means exactly what we wish to express, *the science of life*, has often been used and has of late become not uncommon among good writers."—Whewell, "Philosophy of the Inductive Sciences," vol. i., p. 544 (edition of 1847).

mous; but I should like you to recollect that that is a sacrifice, and that you should not be surprised if it occasionally happens that you see a biologist trespassing upon questions of philosophy or politics, or meddling with human education, because, after all, that is a part of his kingdom which he has only voluntarily forsaken.

Having now defined the meaning of the word "biology," and having indicated the general scope of biological science, I turn to my second question, which is, Why should we study biology? Possibly the time may come when that will seem a very odd question. That we, living creatures, should not feel a certain amount of interest in what it is that constitutes our life, will eventually, under altered ideas of the fittest objects of human inquiry, seem to be a singular phenomenon; but at present, judging by the practice of teachers and educators, this would seem to be a matter that does not concern us at all. I propose to put before you a few considerations which I dare say many of you will be familiar with already, but which will suffice to show—not fully, because to demonstrate this point fully would take a great many lectures—that there are some very good and substantial reasons why it may be advisable that we should know something about this branch of human learning. I myself entirely agree with another sentiment of the philosopher of Malmesbury, that "the scope of all speculation is the performance of some action or thing to be done," and I have not any very great respect for or interest in mere knowing as such. I judge of the value of human pursuits by their bearing upon human interests—in other words, by their utility; but I should like that we should quite clearly understand what it is that we mean by this word "utility." Now, in an Englishman's mouth, it generally means that by which we get pudding or praise, or both. I have no doubt that is one meaning of the word utility, but it by no means includes all I mean by utility. I think that knowledge of every kind is useful in proportion as it tends to give people right ideas, which are essential to the foundation of right practice, and to remove wrong ideas, which are the no less essential foundations and fertile mothers of every description of error in practice. And, upon the whole, inasmuch as this world is, after all, whatever practical people may say, absolutely governed by ideas, and very often by the wildest and most hypothetical ideas, it is a matter of the very greatest importance that our theories of things, and even of things that seem a long way apart from our daily lives, should be as far as possible true, and as far as possible removed from error. It is not only in the coarser practical sense of the word "utility," but in this higher and broader sense, that I measure the value of the study of biology by its utility, and I shall try to point out to you that you will feel the need of some knowledge of biology at a great many turns of this present nineteenth-century life of ours. For example, most of us lay great and very just stress upon the conception which is entertained

of the position of man in this universe, and his relation to the rest of Nature. We have almost all of us been told, and most of us hold by the tradition, that man occupies an isolated and peculiar position in Nature; that though he is in the world he is not of the world; that his relations to things about him are of a remote character, that his origin is recent, his duration likely to be short, and that he is the great central figure round which other things in this world revolve. But this is not what the biologists tell us. At the present moment you will be kind enough to separate me from them, because it is in no way essential to my argument just now that I should advocate their views. Don't suppose that I am saying this for the purpose of escaping the responsibility of their beliefs, because at other times and in other places I do not think that point has been left doubtful; but I want clearly to point out to you that for my present argument they may all be wrong; nevertheless, my argument will hold good. The biologists tell us that all this is an entire mistake. They turn to the physical organization of man. They examine his whole structure, his bony frame, and all that clothes it. They resolve him into the finest particles into which the microscope will enable them to break him up. They consider the performance of his various functions and activities, and they look at the manner in which he occurs on the surface of the world. Then they turn to other animals, and, taking the first handy domestic animal—say a dog—they profess to be able to demonstrate that the analysis of the dog leads them in gross to precisely the same results as the analysis of the man; that they find almost identically the same bones, having the same relations; that they can name the muscles of the dog by the names of the muscles of the man, and the nerves of the dog by those of the nerves of the man, and that such structures and organs of sense as we find in the man such also we find in the dog; they analyze the brain and spinal cord, and find the nomenclature which does for the one answer for the other. They carry their microscopic inquiries in the case of the dog as far as they can, and they find that his body is resolvable into the same elements as those of the man. Moreover, they trace back the dog's and the man's development, and they find that at a certain stage of their existence the two creatures are not distinguishable the one from the other; they find that the dog and his kind have a certain distribution over the surface of the world comparable in its way to the distribution of the human species. What is true of the dog they tell us is true of all the higher animals; and they find that for the whole of these creatures they can lay down a common plan, and regard the man and the dog, the horse and the ox, as minor modifications of one great fundamental unity. Moreover, the investigations of the last three-quarters of a century have proved, they tell us, that similar inquiries carried out through all the different kinds of animals which are met with in Nature will lead us, not in one straight series, but by many roads,

step by step, gradation by gradation, from man at the summit to specks of animated jelly at the bottom of the series; so that the idea of Leibnitz and of Bonnet that animals form a great scale of being in which there is a series of gradations from the most complicated form to the lowest and simplest—that idea, though not exactly in the form in which it was propounded by those philosophers, turns out to be substantially correct. More than this, when biologists pursue their investigations into the vegetable world, they find that they can in the same way follow out the structure of the plant from the most gigantic and complicated trees through a similar series of gradations until they arrive at similar specks of animated jelly, which they are puzzled to distinguish from those which they reached by the animal road.

Thus they have arrived at the conclusion that a fundamental uniformity of structure pervades the animal and vegetable worlds, and that plants and animals differ from one another simply as modifications of the same great general plan.

Again, they tell us the same story in regard to the study of function. They admit the large and important interval which, at the present time, separates the manifestations of the mental faculties observable in the higher forms of mankind, and even in the lower forms, such as we know them, mentally from those exhibited by other animals; but, at the same time, they tell us that the foundations or rudiments of almost all the faculties of man are to be met with in the lower animals; that there is a unity of mental faculty as well as of bodily structure, and that here also the difference is a difference of degree and not of kind. I said "almost all" for a reason. Among the many distinctions which have been drawn between the lower creatures and ourselves, there is one which is hardly ever insisted on,[1] but which may be fitly spoken of in a place so largely devoted to art as that in which we are assembled. It is this, that, while among various kinds of animals it is possible to discover traces of all the other faculties of man, especially the faculty of mimicry, yet that particular form of mimicry which shows itself in the imitation of form, either by modeling or by drawing, is not to be met with. As far as I know, there is no sculpture or modeling, and decidedly no painting or drawing, of animal origin. I mention the fact in order that such comfort may be derived therefrom as artists may feel inclined to take.

If what the biologists tell us is true, it will be needful for us to get rid of our erroneous conceptions of man and of his place in Nature, and substitute for them right ones. But it is impossible to form any judgment as to whether the biologists are right or wrong unless we are able to appreciate the nature of the arguments which they have to offer.

One would almost think that this was a self-evident proposition. I

[1] I think that Prof. Allman was the first to draw attention to it.

wonder what a scholar would say to the man who should undertake to criticise a difficult passage in a Greek play, but who obviously had not acquainted himself with the rudiments of the Greek grammar. And, before giving a positive opinion about these high questions of biology, people not only don't seem to think it necessary to be acquainted with the grammar of the subject, but they have not even mastered the alphabet. You find criticism and denunciation showered about by persons who not only have not attempted to go through the discipline necessary to enable them to be judges, but have not even reached that stage of emergence from ignorance in which the knowledge that such a discipline is necessary dawns upon the mind. I have had to watch with some attention—in fact, I have been favored with a good deal of it myself—the sort of criticism with which biologists and biological doctrines are visited. I am told every now and then that there is a "brilliant article"[1] in so-and-so, in which we are all demolished. I used to read these things once, but I am getting old, and I have ceased to attend very much to this cry of "wolf!" When one does read one of these productions, what one finds generally, on the face of it, is, that the brilliant critic is devoid of even the elements of knowledge in the matter, and that his brilliancy is like the light given out by the crackling of thorns under a pot of which Solomon speaks. So far as I recollect, Solomon makes use of that image for purposes of comparison; but I won't proceed into that matter further.

Two things must be obvious: in the first place, that every man who has the interests of truth at heart must earnestly desire that every well-founded and just criticism that can be made should be made; but it is essential to anybody's being able to benefit by criticism that the critic should know what he is talking about and be in a position to form a mental image of the facts symbolized by the word he uses. If not, it is as obvious in the case of a biological argument as it is in that of an historical or philological discussion, that such criticism is a mere waste of time on the part of the author, and wholly undeserving of attention on the part of those who are criticised. Take it, then, as an illustration of the importance of biological study that thereby alone are men able to form something like a rational conception of what constitutes valuable criticism of the teachings of biologists.[2]

[1] Galileo was troubled by a sort of people whom he called "paper-philosophers," because they fancied that the true reading of Nature was to be detected by the collation of texts. The race is not extinct, but, as of old, brings forth its "winds of doctrine" by which the weathercock-heads among us are much exercised.

[2] Some critics do not even take the trouble to read. I have recently been adjured with much solemnity to state publicly why I have "changed" my opinion as to the value of the paleontological evidence of the occurrence of evolution.

To this my reply is, Why should I, when that statement was made seven years ago? An address delivered from the presidential chair of the Geological Society in 1870 may

Next, I may mention another bearing of biological knowledge—a more practical one in the ordinary sense of the word. Consider the theory of infectious disease. Surely that is of interest to all of us. Now, the theory of infectious disease is rapidly being elucidated by biological study. It is possible to produce from among the lower animals cases of devastating diseases which have all the appearance of our infectious diseases, and which are certainly and unmistakably caused by living organisms. This fact renders it possible, at any rate, that that doctrine of the causation of infectious disease which is known under the name of "the germ-theory" may be well-founded; and, if so, it must needs lead to the most important practical measures in dealing with those most terrible visitations. It may be well that the general as well as the professional public should have a sufficient knowledge of biological truths to be able to take a rational interest in the discussion of such problems, and to see, what I think they may hope to see, that to those who possess a sufficient elementary knowledge of biology they are not all quite open questions.

Let me mention another important practical illustration of the value of biological study. Within the last forty years the theory of agriculture has been revolutionized. The researches of Liebig, and those of our own Lawes and Gilbert, have had a bearing upon that branch of industry, the importance of which cannot be over-estimated; but the whole of these new views have grown out of the better explanation of certain processes which go on in plants, and which, of course, form a part of the subject-matter of biology.

I might go on multiplying these examples, but I see that the clock won't wait for me, and I must, therefore, pass to the third question to which I referred: Granted that biology is something worth studying, what is the best way of studying it? Here I must point out that, since biology is a physical science, the method of studying it must needs be analogous to that which is followed in the other physical sciences. It has now long been recognized that if a man wishes to be a chemist it is not only necessary that he should read chemical books and attend chemical lectures, but that he should actually himself perform the fundamental experiments in the laboratory, and know exactly what the words which he finds in his books and hears from his teach-

be said to be a public document, inasmuch as it not only appeared in the journal of that learned body, but was republished in 1873 in a volume of "Critiques and Addresses," to which my name is attached. Therein will be found a pretty full statement of my reasons for enunciating two propositions: 1. That, "when we turn to the higher *Vertebrata*, the results of recent investigations, however we may sift and criticise them, seem to me to leave a clear balance in favor of the evolution of living forms one from another;" and 2. That the case of the horse is one which "will stand rigorous criticism."

Thus I do not see clearly in what way I can be said to have changed my opinion, except in the way of intensifying it, when in consequence of the accumulation of similar evidence since 1870 I recently spoke of the denial of evolution as not worth serious consideration.

ers, mean. If he does not do that, he may read till the crack of doom, but he will never know much about chemistry. That is what every chemist will tell you, and the physicist will do the same for his branch of science. The great changes and improvements in physical and chemical scientific education which have taken place of late have all resulted from the combination of practical teaching with the reading of books and with the hearing of lectures. The same thing is true in biology. Nobody will ever know anything about biology, except in a dilettant "paper-philosopher" way, who contents himself with reading books on botany, zoölogy, and the like; and the reason of this is simple and easy to understand. It is, that all language is merely symbolical of the things of which it treats; the more complicated the things, the more bare is the symbol, and the more its verbal definition requires to be supplemented by the information derived directly from the handling, and the seeing, and the touching of the thing symbolized: that is really what is at the bottom of the whole matter. It is plain common-sense, as all truth in the long-run is, only common sense clarified. If you want a man to be a tea-merchant, you don't tell him to read books about China or about tea, but you put him into a tea-merchant's office, where he has the handling, the smelling, and the tasting of tea. Without the sort of knowledge which can be gained only in this practical way, his exploits as a tea-merchant will soon come to a bankrupt termination. The "paper-philosophers" are under the delusion that physical science can be mastered as literary accomplishments are acquired, but unfortunately it is not so. You may read any quantity of books, and you may be almost as ignorant as you were at starting, if you don't have, at the back of your minds, the change for words in definite images which can only be acquired through the operation of your observing faculties on the phenomena of Nature.

It may be said: "That is all very well, but you told us just now that there are probably something like a quarter of a million different kinds of living and extinct animals and plants, and a human life could not suffice for the examination of one-fiftieth part of all this." That is true, but then comes the great convenience of the way things are arranged; which is, that, although there are these immense numbers of different kinds of living things in existence, yet they are built up, after all, upon marvelously few plans.

There are, I suppose, about 100,000 species of insects, if not more, and yet anybody who knows one insect—if a properly-chosen one—will be able to have a very fair conception of the structure of the whole. I do not mean to say he will know that structure thoroughly, or as well as it is desirable he should know it, but he will have enough real knowledge to enable him to understand what he reads, to have genuine images in his mind of those structures which become so variously modified in all the forms of insects he has not seen. In fact,

there are such things as types of form among animals and vegetables, and for the purpose of getting a definite knowledge of what constitutes the leading modifications of animal and plant life it is not needful to examine more than a comparatively small number of animals and plants.

Let me tell you what we do in the biological laboratory in the building adjacent to this. There I lecture to a class of students daily for about four and a half months, and my class have, of course, their text-books; but the essential part of the whole teaching, and that which I regard as really the most important part of it, is a laboratory for practical work, which is simply a room with all the materials arranged for ordinary dissection. We have tables properly arranged in regard to light, microscopes, and dissecting-instruments, and we work through the structure of a certain number of animals and plants. As, for example, among the plants we take a yeast-plant, a *Protococcus*, a common mould, a *Chara*, a fern, and some flowering plant; among the animals, we examine such things as an amœba, a *Vorticella*, and a fresh-water polyp. We dissect a star-fish, an earth-worm, a snail, a squid, and a fresh-water mussel. We examine a lobster and a craw-fish, and a black-beetle. We go on to a common skate, a codfish, a frog, a tortoise, a pigeon, and a rabbit, and that takes us about all the time we have to give. The purpose of this course is not to make skilled dissectors, but to give every student a clear and definite conception, by means of sense-images, of the characteristic structure of each of the leading modifications of the animal kingdom; and that is perfectly possible, by going no further than the length of that list of forms which I have enumerated. If a man knows the structure of the animals I have mentioned, he has a clear and exact, however limited, apprehension of the essential features of the organization of all those great divisions of the animal and vegetable kingdoms to which the forms I have mentioned severally belong. And it then becomes possible for him to read with profit, because, every time he meets with the name of a structure, he has a definite image in his mind of what the name means in the particular creature he is reading about, and therefore the reading is not mere reading. It is not mere repetition of words; but every term employed in the description, we will say, of a horse or of an elephant, will call up the image of the things he had seen in the rabbit, and he is able to form a distinct conception of that which he has not seen as a modification of that which he has seen.

I find this system to yield excellent results, and I have no hesitation whatever in saying that any one who has gone through such a course attentively is in a better position to form a conception of the great truths of biology, especially of morphology (which is what we chiefly deal with), than if he had merely read all the books on that topic put together.

The connection of this discourse with the Loan Collection of Scientific Apparatus arises out of the exhibition in that collection of aids to our laboratory-work. Such of you as have visited that very interesting collection may have noticed a series of diagrams and of preparations illustrating the structure of a frog. Those diagrams and preparations have been made for the use of the students in the biological laboratory. Similar diagrams and preparations, illustrating the structure of all the other forms of life we examine, are either made or in course of preparation. Thus the student has before him, first, a picture of the structure he ought to see; secondly, the structure itself worked out; and if, with these aids, and such needful explanations and practical hints as a demonstrator can supply, he cannot make out the facts for himself in the materials supplied to him, he had better take to some other pursuit than that of biological science.

I should have been glad to have said a few words about the use of museums in the study of biology, but I see that my time is becoming short, and I have yet another question to answer. Nevertheless, I must, at the risk of wearying you, say a word or two upon that important subject of museums. Without doubt, there are no helps to the study of biology, or rather to some branches of it, which are, or may be, more important than natural-history museums; but, in order to take this place in regard to biology, they must be museums of the future. The museums of the present do not do by any means so much for us as they might do. I do not wish to particularize, but I dare say many of you seeking knowledge, or in the laudable desire to employ a holiday usefully, have visited some great natural-history museum. You have walked through a quarter of a mile of animals well stuffed, with their long names written out underneath them; and, unless your experience is very different from that of most people, the upshot of it all is that you leave that splendid pile with sore feet, a bad headache, and a general idea that the animal kingdom is a mighty maze without a plan. I do not think that a museum which brings about this result has done all that may reasonably be expected of such an institution. What is needed in a collection of natural history is, that it should be made as accessible and as useful as possible on the one hand to the general public, and on the other to scientific workers. That need is not met by constructing a sort of happy hunting-ground of miles of glass cases, and, under the pretense of exhibiting everything, putting the maximum amount of obstacles in the way of those who wish properly to see anything.

What the public want is easy and unhindered access to such a collection as they can understand and appreciate; and what the men of science want is similar access to the materials of science. To this end the vast mass of objects of natural history should be divided into two parts—one open to the public, the other to men of science, every day, and all day long. The former division should exemplify all the more

important and interesting forms of life. Explanatory tablets should be attached to them, and catalogues, containing clearly-written expositions of the general significance of the objects exhibited, should be provided. The latter division should contain, packed into a comparatively small space, the objects of purely scientific interest. For example, we will say I am an ornithologist. I go to see a collection of birds. It is a positive nuisance to have them stuffed. It is not only sheer waste, but I have to reckon with the ideas of the bird-stuffer, while, if I have the skin, and nobody has interfered with it, I can form my own judgment as to what the bird was like. For ornithological purposes, what is needed is not glass cases full of stuffed birds on perches, but convenient drawers, into each of which a great quantity of skins will go. They occupy no great space, and do not require any expenditure beyond their original cost. But, for the purpose of the public, who want to learn, indeed, but do not seek for minute and technical knowledge, the case is different. What one of the general public, walking into a collection of birds, desires to see, is not all the birds that can be got together; he does not want to compare a hundred species of the sparrow-tribe side by side; but he wishes to know what a bird is, and what are the great modifications of bird-structure; and to be able to get at that knowledge easily. What will best serve his purpose is a comparatively small number of birds, carefully selected, and artistically as well as accurately set up, with their different ages, their nests, their young, their eggs, and their skeletons, side by side, and, in accordance with the admirable plan which is pursued in this museum, a tablet, telling the spectator, in legible characters, what they are and what they mean. For the instruction and recreation of the public, such a typical collection would be of far greater value than any many-acred imitation of Noah's ark.

Lastly comes the question as to when biological study may best be pursued. I do not see any valid reason why it should not be made, to a certain extent, a part of ordinary school-training. I have long advocated this view, and I am perfectly certain that it can be carried out with ease, and not only with ease, but with very considerable profit to those who are taught; but then such instruction must be adapted to the minds and needs of the scholars. They used to have a very odd way of teaching the classical languages when I was a boy. The first task set you was to learn the rules of the Latin grammar in the Latin language—that being the language you were going to learn. I thought then that this was an odd way of learning a language, but did not venture to rebel against the judgment of my superiors. Now, perhaps, I am not so modest as I was then, and I allow myself to think it was a very absurd fashion. But it would be no less absurd if we were to set about teaching biology by putting into the hands of boys a series of definitions of the classes and orders of the animal kingdom, and making them repeat them by heart.

That is a very favorite method of teaching, so that I sometimes fancy the spirit of the old classical system has entered into the new scientific system, in which case I would much rather that any pretense at scientific teaching were abolished altogether. What really has to be done is to get into the young mind some notion of what animal and vegetable life is. You have to consider in this matter practical convenience as well as other things. There are difficulties in the way of a lot of boys making messes with slugs and snails; it might not work in practice. But there is a very convenient and handy animal which everybody has at hand, and that is himself; and it is a very easy and simple matter to obtain common plants. Hence, the broader facts of anatomy and physiology can be taught to young people in a very real fashion by dealing with the broad facts of human structure, such as hearts, lungs, and livers. Such viscera as they cannot very well examine in themselves may be obtained from the nearest butcher's shop. In respect to teaching them something about the biology of plants, there is no practical difficulty, because almost any of the common plants will do, and plants do not make a mess—at least they do not make an unpleasant mess; so that, in my judgment, the best form of biology for teaching to very young people is elementary human physiology on the one hand, and the elements of botany on the other; beyond that I do not think it will be feasible to advance for some time to come. But then I see no reason why in secondary schools, and in the science classes, which are under the control of the Science and Art Department—and which, I may say, in passing, have, in my judgment, done so very much for the diffusion of a knowledge over the country—I think that, in those cases, we may go further, and we may hope to see instruction in the elements of biology carried out, not, perhaps, to the same extent, but still upon somewhat the same principle, as we do here. There is no difficulty, when you have to deal with students of the ages of fifteen or sixteen, in practising a little dissection and getting a notion, at any rate, of the four or five great modifications of the animal form, and the like is true in regard to plants.

While, lastly, to all those who are studying biological science with a view to their own edification, or with the intention of becoming zoölogists or botanists; to all those who intend to pursue physiology—and especially to those who propose to employ the working years of their lives in the practice of medicine—I say that there is no training so fitted, or which may be of such important service to them, as the thorough discipline in practical biological work which I have sketched out as being pursued in the laboratory hard by.

I may add that, beyond all these different classes of persons who may profit by the study of biology, there is yet one other. I remember, a number of years ago, that a gentleman who was a vehement opponent of Mr. Darwin's views, and had written some terrible articles against them, applied to me to know what was the best way in which

he could acquaint himself with the strongest arguments in favor of evolution. I wrote back in all good faith and simplicity, recommending him to go through a course of comparative anatomy and physiology, and then to study development. I am sorry to say he was very much displeased, as people often are with good advice. Notwithstanding this discouraging result, I venture, as a parting word, to repeat the suggestion, and to say to all the more or less acute lay and clerical "paper-philosophers"[1] who venture into the regions of biological controversy—Get a little sound, thorough, practical, elementary instruction in biology.

HOW THE EARTH WAS REGARDED IN OLD TIMES.[2]

FROM THE FRENCH OF FLAMMARION.

WE are too apt in these times of popular education, and the cheap diffusion of knowledge, to forget the cost of scientific truth. We formulate a fact or principle, and administer it in the school-room, with but little regard to the circumstance that it may have cost thousands of years of toil to discover and establish it. We have found out, for example, a great deal about the figure, motions, and astronomical relations of the earth, with such exactness that, as Prof. Young tells us, we know the semi-diameter of our globe at the equator within two hundred feet—while to go "around the world" is now a mere frolic; and all this knowledge is given to children in an hour's lesson. But how few appreciate the long struggle of the human intellect in arriving at these simple results! Let us hastily glance at the early efforts of the human mind in trying to find out what sort of thing this earth is, in its form, extent, and relation to the heavenly bodies that surround it.

The history of the growth of any branch of knowledge has a double interest: that which comes from the knowledge itself, and its relation to the history of the operations of the human mind. Men think under the limitations of their times both as regards the extent

[1] Writers of this stamp are fond of talking about the Baconian method. I beg them, therefore, to lay to heart these two weighty sayings of the herald of Modern Science:

"Syllogismus ex propositionibus constat, propositiones ex verbis, verba notionum tesseræ sunt. Itaque si notiones ipsæ (*id quod basis rei est*) confusæ sint et temere a rebus abstractæ, nihil in iis quæ superstruuntur est firmitudinis."—("Novum Organon," ii., 14.)

"Huic autem vanitati nonnulli ex modernis summa levitate ita indulserunt, ut in primo capitulo Geneseos et in libro Job et aliis scripturis sacris, philosophiam naturalem fundare conati sint; *inter vivos quærentes mortua*."—(*Ibid.*, 65.)

[2] The cuts of this article are from Flammarion's "History of the Heavens," and we have made free use of the text of Blake's "Astronomical Myths," which is based on Flammarion's work.

of knowledge and the intellectual processes to which they are habituated. They reason as they can on such materials as they have. If they have not learned to observe, they come to conclusions without observations. If they do not know that there are such things as laws of Nature, their inquiries are not directed to find them. If they

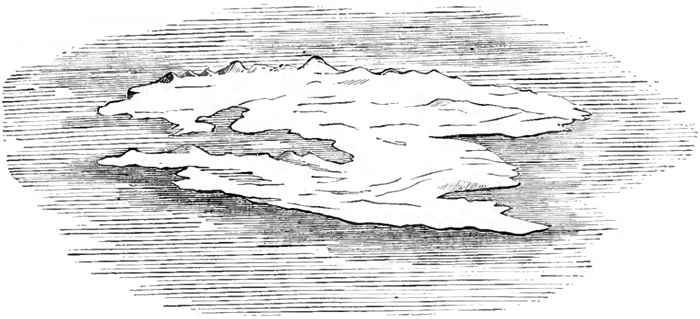


FIG. 1.—THE EARTH FLOATING.

think that the mind is the measure of Nature, they will search in their own reflections for the explanations of Nature; and when they have got out plausible results, or which agree with logic, they will impose their conclusions upon Nature as if they represented the truth. The human mind is essentially active and will make theories; and the

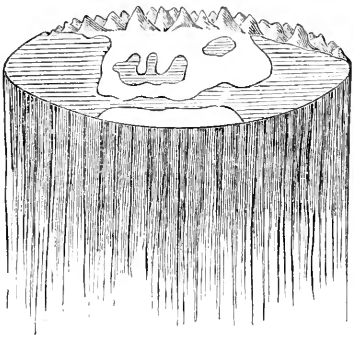


FIG. 2.—THE EARTH WITH ROOTS.

less its knowledge the feebler are the restraints of reason and the bolder the spirit of speculation. We must therefore expect that, in regard to the knowledge of the earth when nothing was actually known about it in early times, there must have been an enormous amount of crude conjecture, futile reasoning, and absurd fancy, or rather much that so appears to us now, although it may have been put forth at first as sober and honest belief.

Aristotle, who lived in the fourth century B. C., and studied Na-

ture with great earnestness and assiduity, held many views concerning the earth that were very reasonable for his time. Yet, in the absence of facts, nothing was left for him but to rely upon logic. He had certain ideas of what is *natural* and what is *perfect*, and from

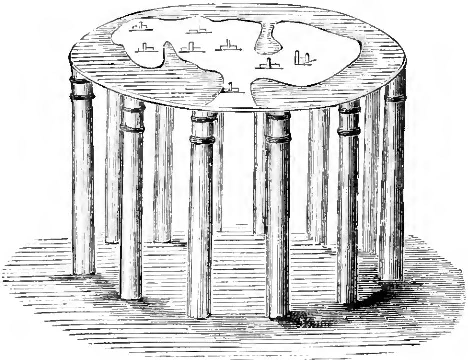


Fig. 3.—The Earth of the Veda Priests.

these he reasoned as to what *must be* and therefore what is. To the question whether the earth turns or the heavens turn, he replies that the earth is *evidently* in repose, not only because we see it to be so, but because it is a necessity that it should be, that is, because repose is *natural* to the earth. If it be asked why the stars must move around

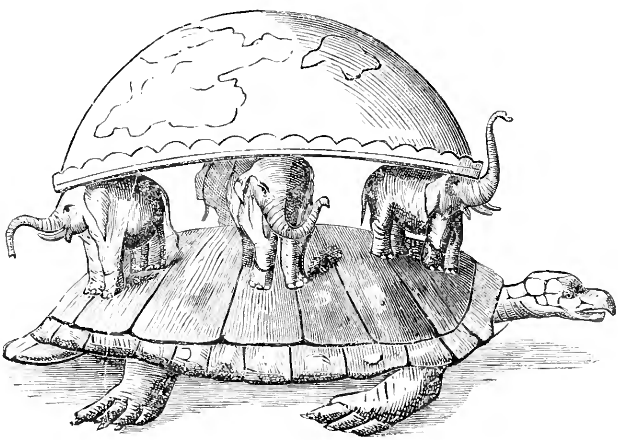


Fig. 4.—The Hindoo Earth.

the earth, he replies, it is natural that they should, because a circle is the most *perfect* line, because it has no ends, and it must therefore be described by the perfect stars. That the earth is the centre of the universe, and is at rest, is furthermore proved by Aristotle from theo-

logical considerations: thus, everything which performs any act has been made for the purpose of that act. Now, the work of God is immortality, from which it follows that all that is divine must have an eternal motion. The heavens have a divine quality, and for this reason they have a spherical shape and move eternally in a circle. Now,

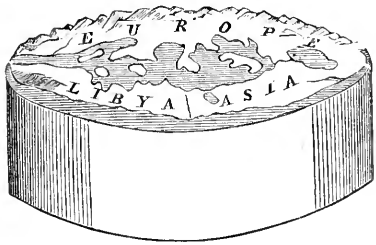


FIG. 5.—ANAXIMANDER'S CYLINDRICAL EARTH.

when a body has a circular motion, one part of it must remain at rest in the centre; the earth is in the centre, and therefore motionless.

Aristotle, however, entertained many sensible views regarding the earth which were of course greatly "in advance of his times," and, among others, that the earth was spherical, for which he offered rea-

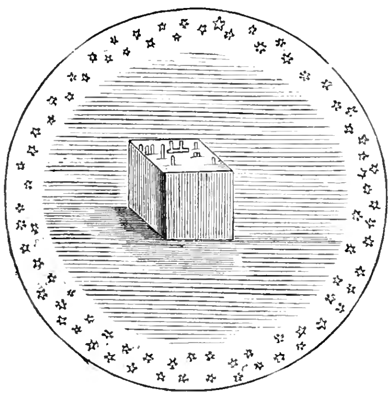


FIG. 6.—PLATO'S CUBICAL EARTH.

sons that are valid now. But how it could remain suspended in one place without any foundation to rest upon, puzzled him.

Among the various causes which in the absence of facts determined men's geographical opinions, one was the patriotic sentiment by which ignorant people were led to magnify their native country. According to the prepossessions of race, each one thought his own country to be located at the centre of the earth. Thus the Hindoos, who lived near the equator, and the Scandinavians, who lived nearer the pole, apply each a term to their own country which means

"the central habitation." The Greeks made Olympus the centre; the Egyptians, Thebes; the Assyrians, Babylon; the Hebrews, Jerusalem; while the Chinese always called their country the central empire. This is natural enough (as Aristotle would say), because most people regard their neighborhood as the centre of the universe, and the number of central railroads shows the continued force of this geometric idea.

One of the most primitive ideas concerning the earth represented it as a vast plain or flat island, surrounded on all sides by an inaccessible and interminable ocean. At the extremities and around the borders were placed the "fortunate isles," or imaginary regions, peopled by giants, pygmies, and extraordinary beings. The circumscribing

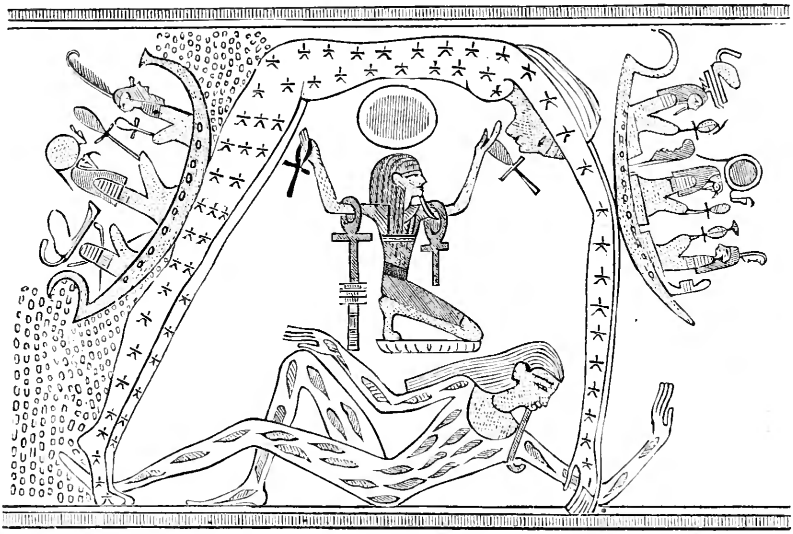


FIG. 7.—EGYPTIAN REPRESENTATION OF THE HEAVENS AND EARTH.

water surrounding the irregular outlines of the land led to the idea of a universal ocean. But, when men began to have experience of the sea by early navigation, the idea of a circular horizon always observed led to the notion that the ocean was bounded, and the whole earth came to be represented as contained in a circle, beneath which were roots reaching downward without end.

The priests of Veda, the scriptures of Buddhism, asserted that the earth was supported on twelve columns, which they very ingeniously turned to their own account by asserting that these columns were sustained by virtue of the sacrifices that were made to the gods, so that if these were not made the earth would collapse.

"These pillars were invented in order to account for the passing of the sun beneath the earth after his setting, for which at first they

were obliged to imagine a system of tunnels that gradually became enlarged to the intervals between the pillars."

The Hindoos held the earth to be hemispherical, and to be supported like a boat turned upside down upon the heads of four elephants, which stood on the back of an immense tortoise. It is usually said that the tortoise rested on nothing, but the Hindoos maintained that it floated on the surface of the universal ocean. The learned Hindoos, however, say that these animals were merely symbolical, the four elephants meaning the four directions of the compass, and the tortoise meaning eternity. The idea that the earth floated long prevailed, and was adopted by Thales, the early Greek philosopher, and by Seneca several centuries later.

Anaximander, a philosopher of the sixth century before Christ, represented the earth as a cylinder, the upper face alone of which is inhabited. He computed its proportions, and stated that it is one-third as high as its diameter; and he declared that it floats freely in

Fig. 8.—The Earth of the Later Greeks.

the centre of the celestial vault, because there is no reason why it should move to one side rather than to the other. Leucippus, Democritus, Heraclitus, and Anaxagoras, all agreed with him, and Anaximenes added the opinion, in consequence of the importance of air in the world, that the earth is supported on compressed air.

Plato was a mathematician, and excogitated the universe out of the depths of his geometrical consciousness. In explaining how things came about, he said that matter in itself had no form or properties, but God in the beginning invested it with a sort of triangular constitution. Afterward, taking a certain number of these primitive triangles, he composed the four primary elements. Fire, the most subtile, is made up of the smallest number of triangles, and has the figure of a pyramid. Water-particles are solids of twenty faces, while the earth-element is cubical or bounded by right-angled triangles. The cube with its six equal faces appeared to Plato to be the most *perfect* of solids, and therefore most suitable for the earth, which was to stand in the centre of the universe.

How the earth is supported was ever a perplexing question among ignorant nations. Thus, in the opinion of the old Greenlanders, as handed down from antiquity, the earth is upheld by pillars, which are so consumed by time that they often crack, and, were it not that they are sustained by the incantations of the magicians, the earth would long since have broken down.

It is hardly possible for us now to enter into that gross anthropomorphic state of mind by which, in primitive times, the phenomena of the universe were all represented in terms of human personality; nor can we even say how literally such views were held. But cer-

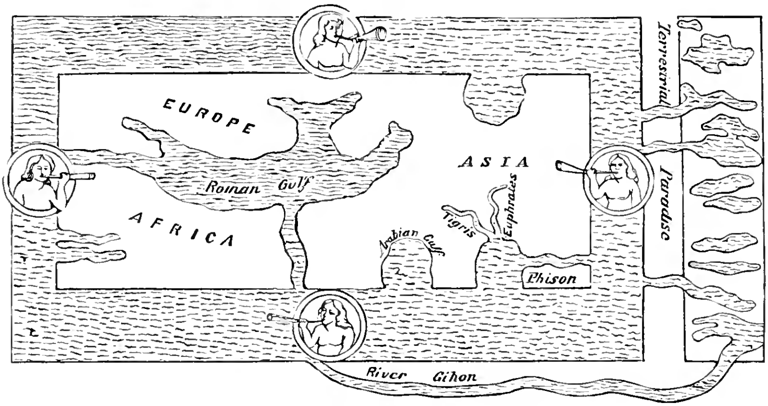


FIG. 9—THE COSMOGRAPHY OF COSMAS.

tainly some of the representations are funny and fantastic. Thus, "an ancient Egyptian papyrus in the Library of Paris gives a very curious hieroglyphical representation of the universe. The earth is here imaged under the form of a reclining figure, and is covered with leaves. The heavens are personified by a goddess, who forms the vault by her star-bespangled body, which is elongated in a very peculiar manner. Two boats, carrying one the rising sun and the other the setting sun, are represented as moving along the heavens over the body of the goddess. In the centre of the picture is the god Maon, a divine intelligence, which presides over the equilibrium of the universe."

Strabo, one of the greatest geographers of antiquity—born A. D. 19—held to the sphericity of the earth, but of course regarded it as the motionless centre of the universe. He considered the moon and stars as only meteors, nourished by the exhalations of the ocean, and firmly maintained that no part of the earth can be inhabited save that which was known to the ancients. The form of the habitable world he held to be like that of a cloak, measuring in length from east to west 70,000 stadia (about 8,000 miles), while its breadth is less than 30,000 stadia (3,600 miles). It is bounded by regions unin-

habitable, on the one side from excessive heat and on the other from excessive cold. "The habitable world was thus much longer from east to west than it was broad from north to south: whence come our terms *longitude*, whose degrees are counted in the former direction, and *latitude*, reckoned in the latter direction."

In the fifth, sixth, and seventh centuries of the Christian era science made little progress in any direction, and, in regard to the ideas of the earth, the fathers of the Church contented themselves with pouring out their invective upon the idea that it is a globe, employing Scriptural reasons, which continued to be used even in the fifteenth century by the monks of Salamanca. In the year A. D. 535, Cosmas, surnamed *Indicopleustes*, after his voyage to India, wrote a work entitled "Christian Topography," in which he propounded the system of a square earth, with solid walls for supporting the heavens. He undertook to bring the opinions of the fathers into a methodical

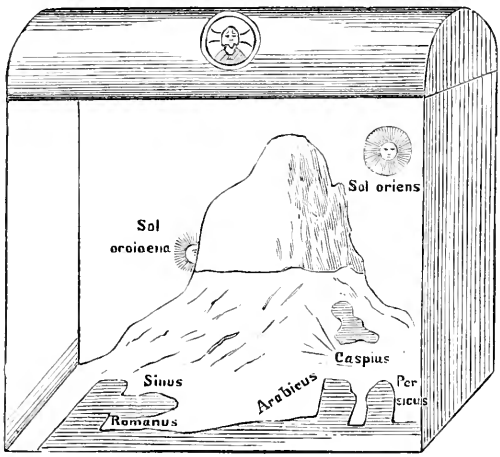


FIG. 10.—THE EARTH AND FIRMAMENT.

shape, and to explain the heavens and the earth in accordance with Scripture. We quote M. Flammarion's description of his system:

"According to Cosmas and his map of the world, the habitable earth is a plane surface. But, instead of being supposed, as in the time of Thales, to be a disk, he represented it in the form of a parallelogram, whose long sides are twice the shorter ones, so that man is on the earth like a bird in a cage. This parallelogram is surrounded by the ocean, which breaks in in four great gulfs, namely, the Mediterranean and Caspian Seas, and the Persian and Arabian Gulfs.

"Beyond the ocean in every direction there exists another continent, which cannot be reached by man, but of which one part was once inhabited by him before the deluge. To the last, just as in other maps of the world and in later systems, he placed the *Terrestrial Paradise* and the four rivers that watered Eden, which come by subterranean channels to water the post-diluvian earth.

"After the fall, Adam was driven from paradise, but he and his descendants remained on the coasts until the deluge carried the ark of Noah to our present earth.

"On the four outsides of the earth rise four perpendicular walls which surround it and join together at the top in a vault, the heavens forming the cupola of this singular edifice.

"The world according to Cosmas was, therefore, a large oblong box, and it was divided into two parts. The first, the abode of men, reaches from the earth

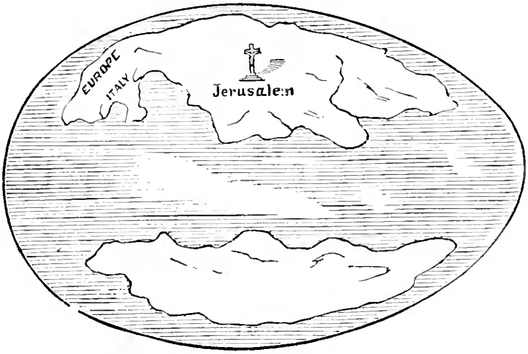


Fig. 11.—The Earth as an Egg.

to the firmament, above which the stars accomplish their revolutions; there dwell the angels, who cannot go any higher. The second reaches upward from the firmament to the upper vault, which crowns and terminates the world. On this firmament rest the waters of the heavens.

"Cosmas justifies this system by declaring that, according to the doctrine of the fathers and the commentators on the Bible, the earth has the form of the tabernacle that Moses erected in the desert; which was like an oblong box, twice as long as broad. But we may find other similarities—for this land beyond the ocean recalls the Atlantic of the ancients, and the Mohammedans, and Orientals in general, say that the earth is surrounded by a high mountain, which is a similar idea to the walls of Cosmas.

"God, he says, in creating the earth, rested it on nothing. The earth is, therefore, sustained by the power of God, creator of all things, supporting all things by the word of his power. If below the earth or outside of it anything existed, it would fall of its own accord. So God made the earth the base of the universe, and ordained that it should sustain itself by its own proper gravity."

Cosmas says that the earth, a sort of great square box circumscribed on all sides by high walls, is divided into three parts: first, the habitable earth, which occupies the middle; secondly, the ocean, which surrounds this on all sides; and, thirdly, another dry land, which surrounds the ocean, terminated itself by these high walls, on which the firmament rests. The habitable earth is always higher as we go north, and the southern countries much lower, so that the Tigris and the Euphrates, which run south, are more rapid than the Nile, which runs northward. The sun, moon, planets, and comets, all set behind

a large conical mountain; and accordingly as the sun disappears and emerges at points higher or lower is the varying length of day and night. On his view the stars were impelled by angels, who either carried them on their shoulders, rolled them in front of them, or drew them behind, it being remarked that "each angel that pushes a star takes great care to observe what the others are doing, so that the relative distances between the stars may always remain what they ought to be."

The learned Bede, known as the Venerable, who lived in the eighth century, regarded the earth as formed upon the model of an egg. He says:

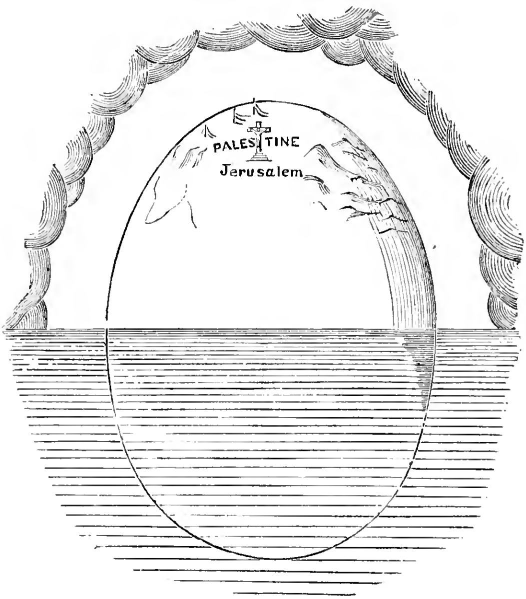


FIG. 12.—THE EARTH AS A FLOATING EGG.

"The earth is an element placed in the middle of the world, as the yolk is in the middle of an egg; around it is the water, like the white surrounding the yolk; outside that is the air, like the membrane of the egg; and round all is the fire, which closes it in as the shell does. The earth, being thus in the centre, receives every weight upon itself; and, though by its nature it is cold and dry in its different parts, it acquires, accidentally, different qualities; for the portion which is exposed to the torrid action of the air is burned by the sun, and is uninhabitable; its two extremities are too cold to be inhabited; but the portion that lies in the temperate region of the atmosphere is habitable. The ocean, which surrounds it by its waves as far as the horizon, divides it into two parts, the upper of which is inhabited by us, while the lower is inhabited by our antipodes; although not one of them can come to us, nor one of us to them."

It is said that a great number of the maps of the world, at the period of Bede, followed this idea, although the necessity was per-

ceived that the great earth-egg should not be left without some kind of support. To meet this requirement Edrisi, an Arabian geographer of the eleventh century, broached the idea that the earth is like an egg, with one-half plunged in water. According to him, the known world forms only a single half of the egg, which floats in the great ocean like an egg in a basin. This notion got currency with artists and map-makers, and continued, it is said, as a mode of representing the earth for many centuries.

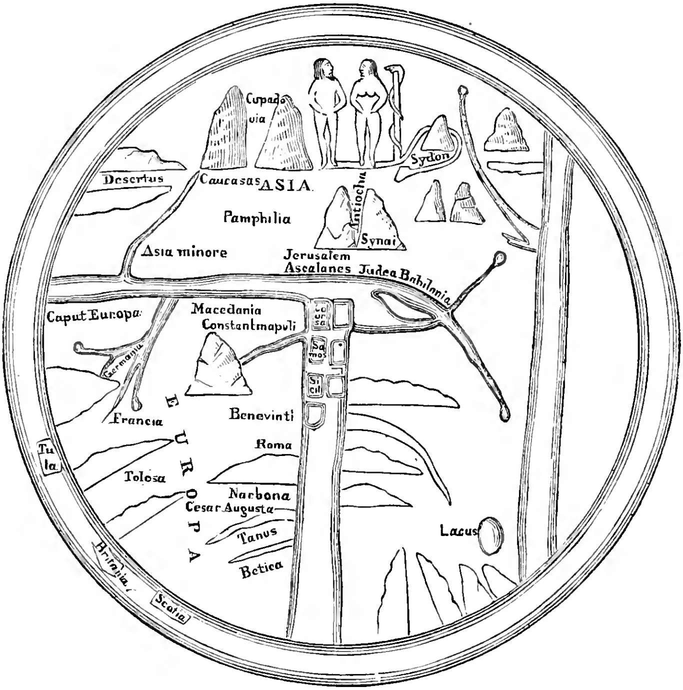


FIG. 13.—EIGHTH-CENTURY MAP OF THE WORLD.

"In a manuscript commentary on the Apocalypse, which is in the library of Turin, is a very curious chart, referred to the tenth, but belonging possibly to the eighth century. It represents the earth as a circular planisphere. The four sides of the earth are each accompanied by a figure of a wind, as a horse on a bellows, from which air is poured out, as well as from a shell in his mouth. Above, or to the east, are Adam and Eve, with the serpent. To their right is Asia, with two very elevated mountains—Cappadocia and Caucasus. Thence comes the river Eusis, and the sea into which it falls forms an arm of the ocean which surrounds the earth. This arm joins the Mediterranean, and separates Europe from Asia. Toward the middle is Jerusalem, with two curious arms of the sea running past it; while to the south there is a long and straight sea in an east and west direction. The various islands of the Mediterranean are put in a square patch, and Rome, France, and Germany, are indicated, while Thula, Britannia, and Scotia, are marked as islands in the northwest of the ocean that surrounds the whole world."

And so the history goes on, geographical facts being mingled with fable, superstition, ancient mythology, and modern theology, until the era of maritime discovery, inaugurated by adventurers like Columbus, who discovered a new continent, and Magalhaens, who first circumnavigated the globe. From that period the advance of geographical knowledge has been in a great measure freed from the embarrassments of superstition, and has been steady and rapid in all the various fields of exploration.

HOW THE EARTH WAS EXPLORED IN 1876.[1]

FROM JUDGE DALY'S ADDRESS.

FROM the mode of regarding the earth entertained in old times, let us now pass to the modern method, and what has been accomplished by geographical investigation in a single year. No better illustration can be found of the great change which science has wrought in the mental habits of man than the contrast between the empty speculations of the olden time, and the immense and positive results of observation and exploration by which our geographical knowledge has been augmented, in even a single year. Judge Daly's annual *résumé* of the previous year's work in geographical inquiry, given before the society of which he is president, is so careful, so trustworthy, and so complete, that it is looked for with eagerness by many readers. By his kind permission, we avail ourselves of the discourse, condensing some parts and quoting others. Those who do not like this mangling of an author's work had better get the discourse in its full text, which will be issued in pamphlet form.

We are informed that the past year has been marked, not only by investigations and discourses, but by the establishment of several new geographical societies, and a large increase in the membership of the old. Having their origin in the "Society of the Argonauts" founded in Venice in 1688, there are now thirty-eight such societies in existence. Physical geography, to which I shall first refer, is a line of inquiry in which there has been great activity during the past year, as shown by the number of works that have been published, and the papers that have been read upon the various branches of this great subject.

"At a meeting of the British Association at Glasgow, last September, Sir William Thomson considered the subject of the interior of the earth. He said that the greatest depth that had been reached in observations of underground temperature was scarcely one kilometre

[1] Condensed from the annual address of Chief-Justice Charles P. Daly, President of the American Geographical Society, delivered January, 1877.

(which is less than a mile); that, whatever might be the age of the earth, we might be sure that it was solid in the interior—not through its whole volume, as there were spaces in volcanic regions occupied by liquid lava, but that this portion was small in comparison to the whole—and that any geological hypothesis must be rejected which assumes that the earth is a shell resting on a liquid mass. He also considered the question, first, of the accuracy of the earth as a timekeeper; and, second, the permanence of its axes of rotation. Since the first known observation of an eclipse of the moon at Babylon, on the 19th of March, 721 B. C., the earth has lost a portion of its velocity, and is now, as a timekeeper, going slower; and his observation upon the question of the earth's axis was, in effect, that if causes existed adequate to produce a change in the position of the axis by the upheaving of the surface, or otherwise, the result, even if sudden, would not be very great, or produce any extraordinary effect. Many important observations were made, at the same meeting, upon the tides, ocean temperature, and currents, and upon the physical geography of the sea, founded upon the results of the voyage of the Challenger."

Of this expedition Sir Wyville Thomson has given the general results. The superficial area of the world is 197,000,000 square miles, of which 140,000,000 are covered by the sea at an average depth of 15,000 feet. The floor of this region is, to a certain degree, comparable to the land. It has its hills, valleys, and great plains; its various soils; its climates, and its special races of inhabitants, depending on the conditions of climate and soil for their distribution.

"The vessel departed from England in December, 1872. She crossed the Atlantic four times in 1873, in a course of nearly 20,000 miles. In 1874 she went southward from the Cape of Good Hope, dipping within the antarctic circle as far as she could, and then traversed the Australian and New Zealand seas and the interior of the Malay Archipelago, arriving at Hong-Kong on November 10, 1874, after a run in that year of 17,000 miles. In 1875 she traversed the Pacific, in a course of about 20,000 miles, and then crossed the Atlantic for the fifth time, reaching England May 24, 1876. The three general results are—1. The knowledge obtained of the contour of the bottom, and the nature of the deposits now being formed. 2. The distribution of deep-sea climate. 3. The nature and distribution of the peculiar race of animals now found at the bottom of the sea. In the Pacific there is an enormous extension of water of great depth—in many cases beyond 18,000 feet. In the North Atlantic the greater portion has a depth of 12,000 feet; and in the South Atlantic, on each side of what is known as the Dolphin rise, there are troughs usually 18,000 feet deep, which form marked depressions roughly parallel with the arc of the South American and African Continents. The whole bottom of the sea is gradually receiving accumulations, giving rise to formations which must be regarded as the rocks of the future. The *débris* of

the land was found to be carried out into the sea some hundreds of miles, and clays were being formed, mixed up with the *débris* of animals. Within a certain distance of the land the deposits, to a great extent, were formed of this material. Over a great part of the North Atlantic there is being deposited the *Globigerina ooze*—composed, principally, of small chambered shells, extremely minute; and these shells were found in enormous quantities. This deposit is almost entirely of carbonate of lime, and the only rock it could form would be limestone; therefore, over a large part of the North Atlantic, and over many other parts of the world, this limestone is being laid down." These creatures live at and near the surface, and thence the whole of this sort of material at the bottom is derived. "It might be supposed that this formation ought to be as universal as is the distribution of these animals on the surface. Singularly enough, this is not the case. At the depth of 12,000 feet the shells become rotten and yellow; at 13,000 feet there are no shells, and the bottom is one of homogeneous red mud, which, instead of consisting of carbonate of lime, is ordinary clay. I may here interpolate a fact to show how abundant animal life is at or very near the surface of the ocean. The steamer Great Eastern was lately in dock at Milford Haven for the examination of her bottom, which had not been scraped since 1867. Her bottom was found covered with an enormous multitude of mussels, clustered together in one dense and continuous deposit, extending over 52,000 square feet, and which, upon a calculation made, amounted to not less than *three hundred tons*' weight, or enough to load with a full cargo two ordinary collier brigs.

"Another curious fact observed in the voyage of the Challenger was, that all over the bottom of the sea there is a large quantity of pumice, showing that there are volcanoes, either below the water or otherwise, that are constantly throwing out material. This pumice, which is the froth of lava, is frequently so light as to float on the water, and wherever they were, in any part of the world, they saw it moved about by the current over the surface of the sea. They found living in the sea, on the surface, or just below, a great quantity of beautiful organisms called *Radiolarians*. They increase with the depth, and many occur at great depths that are not found on the surface at all. The impression formed was that they lived all through the sea, and down to the greatest depths.

"The whole bottom of the Pacific, or the greater part of it, is red clay. The temperature of the ocean at 13,000 feet is very low. It is usually but a little above the freezing-point at the bottom of the Pacific and the Atlantic, and portions of the Southern Sea. The general temperature gradually falls from the surface until the depth of 13,000 feet, below which there is, throughout the sea, a uniform temperature of 37° or 34°, or a little below the freezing-point. The question arose, Whence does the ocean derive this low and uniform temperature? It

is a question of great difficulty; and the conjecture made is, that it is an inflow of the cold water from the vast area of the antarctic."

The geographical work of the United States has been more limited than usual, owing to delay and smallness of appropriations. The Coast Survey continues its work: in the Gulf of Mexico careful soundings have been made, and observations on the temperature of the water and the flow of currents, which will throw light on the Gulf Stream. Triangulations were pushed eastward from the Pacific Coast Range to the Sierra Nevada, some of the triangles observed having sides over 150 miles long; a series of telegraphic determinations of longitude have been made for the purpose of correcting our charts of the West India Islands, one point at least having been located on each island. Triangulation along Lakes Ontario, Erie, and Michigan, has been continued, the topography of Niagara River completed, many points determined for the State survey of Michigan, and the elevation of the Great Lakes newly determined. Lake Ontario is found to be 247.25 feet and Lake Erie 573.58 feet above mean tide at New York. Reports of geographical and topographical work in Montana, the Yellowstone Park, Southern Colorado, Northern New Mexico, and Arizona, have been issued. The geographical surveys west of the 100th meridian, under Lieutenant Wheeler, have been continued. About 25,000 square miles were traversed by the various parties. Some interesting Spanish mines were found in New Mexico. A survey was carried on in the neighborhood of Lake Tahoe, in California. The depth of the lake was found to exceed 2,200 feet. The examination of the Colorado River, with reference to determining the practicability of diverting it from its channel to irrigate the deserts of Southeastern California, has been completed. The lowest part of the desert is 200 feet below the sea, and it was found that an area of 1,600 square miles could be flooded; but constantly-shifting sands would make it a continual expense, and the evaporation from the surface of such a lake would exceed the water flowing in the Colorado in a dry season. Thirteen atlas sheets of Lieutenant Wheeler's survey have been issued; they are upon a scale of eight miles to the inch, and cover a large part of Nevada, Utah, Arizona, New Mexico, and Colorado. The survey of the Territories under Profs. Hayden and Powell was carried on, and much has been learned of the region embracing Colorado, Utah, and Southeastern Nevada. A triangulation party climbed and measured Blanco Peak, near Fort Garland, in Colorado, which, if not the highest, is next to the highest peak in the Rocky Mountains. It is 14,464 feet high. Over fifty of the most elevated peaks in that range are in the State of Colorado, running from 14,000 to 14,500 feet, so close that the utmost care has been required to determine which is the highest.

Eastern Utah was surveyed from the Colorado River to and over the Wahsatch Mountains between parallels 38° and 39° 15′. The region

is characterized by great plateaus bounded by lines of cliffs from 1,000 to 2,000 feet in height, varying from 20 to 200 miles in length, the whole intersected with a network of deep and narrow cañons, presenting nearly impassable barriers. Of one section of about 7,000 square miles, only about one per cent. is available for agriculture; about five per cent. is covered by pine and spruce, the remainder being a desert waste. There are large quantities of excellent coal, but no precious metals were discovered. The average elevation of this region is about 7,000 feet. Another section in Southwestern Utah and Southeastern Nevada of about 4,000 square miles was found one of the most barren regions of the whole Great Basin. It is marked by ranges rising to 9,000 feet, with broad desert valleys between. Little timber-land or land fit for cultivation was found, the pasturage being of the poorest quality. The climate is milder than that of Eastern Utah, and very dry, the annual rainfall not exceeding four inches. "There is no coal in this region, but it is known to contain large amounts of silver. The well-developed mining district of Pioche was within the region examined, and also a newly-organized district at Leeds, on the Virgin River, Utah, where silver, instead of occurring in veins, is disseminated in the form of horn-silver, through a stratum of sandstone belonging to the Jura Trias. Between 4,000 and 5,000 men have gathered at this last-named district (Leeds) within the past few months."

Extensive collections have been made illustrative of the arts and industries of the Indian tribes, embracing totemic carvings, stone implements, clothing, ornaments, furniture, and manufactures, of the Pueblo race; heraldic columns from Vancouver's Island, of painted wood from 25 to 40 feet high, erected in front of their dwellings, which are communal, holding from 100 to 300 people. These houses are made from slabs rived out of great tree-trunks with wooden wedges and stone mallets. Canoes were obtained 60 feet in length, dug from single logs; many tons of ancient stone implements, said to surpass in beauty of finish any aboriginal remains of like nature hitherto discovered, together with pottery, have been forwarded to the Smithsonian Institution from Southern California. The United States Signal Service Corps "is making rapid advances toward a complete knowledge of the conditions and causes of the American climate. They have nearly completed the most extensive collection of altitudes of places in North America which has ever been gathered. The list includes several thousand profiles, representing almost every railroad and canal. From this and other data they are making a relief model of North America on a large scale. A telegraph-line has been built by them from Central Texas across the Llano Estacado, that dreaded waterless desert, and one across the high and arid plateaus and ranges of Southern New Mexico and Arizona to San Diego, on the Pacific. This gives an unbroken line from Savannah along the southern border of the United States, stretching from ocean to ocean. Thirty

meteorological stations are placed along the line, the highest being 6,800 feet above the sea. Another line of stations follows the Rio Grande River from its mouth to the elevated plateau of Colorado.

"The Mexican telegraph-lines now extend from the mouth of the Rio Grande River to San Luis, thence to Tampico, and thence through Vera Cruz along the coast nearly to the extremity of Yucatan. The Signal Service are preparing to place stations down even to Yucatan. The Gulf of Mexico has been nearly encircled with a telegraph-line, along which meteorological stations will be placed at such short intervals that no hurricane or storm can move from the Gulf without notice of its escape and the direction of its flight being given at once to the whole country.

"Arrangements have been made for a chain of stations to the extreme eastern end of the West Indies, all connected by telegraph with the Washington office. If Congress is wise enough to give sufficient appropriation to carry out these excellent plans, it will be impossible for any hurricane to enter the United States from the south unheralded, for hourly bulletins of its progress can be posted in every seaport. Who can estimate the lives and treasure that such an arrangement may save? Congress cannot be too generous to the Signal Service.

"To show the power of the telegraph in this connection, I may mention that General Myer recently sent, at twelve o'clock at night, an order to each meteorological station in this country. It was unexpected by the corps, but so perfect is the discipline that within ninety minutes the Washington office received answers from every station, even including that on the lofty elevation of Pike's Peak, and the lonely desert of Fort Yuma.

"At General Myer's suggestion, an international meteorological organization was effected in 1873. Observations are now taken once a day, *simultaneously*, at every meteorological station in the world, and the results forwarded to the Signal Service Office at Washington.

"Every day this office publishes a bulletin, giving the record of these simultaneous observations from all stations. The date of the bulletin is necessarily long enough after the observations to admit of their reaching Washington. The climate of the world is thus placed under our eyes at once. When this is carried to perfection, the laws that govern climate may be determined."

The petrified forest in the desert of Humboldt County, Northwestern Nevada, has been examined. The stumps of the trees now transformed into rock are found in an upright position, with their roots imbedded in the soil as when growing—many of the stumps measuring from fifteen to twenty feet in circumference; and the ground was found strewed with trunks and limbs in the same petrified state, retaining their natural shape and size. There were no liv-

ing trees, nor any trace of vegetation, in the vicinity, except a growth of stunted sage-brush.

"The largest tree yet found in California was discovered during the year in King's River Valley, Fresno County. Measured from the highest point to which a man could reach, it was found to be 150 feet in circumference, within a few inches, and its height was estimated at 160 feet. It is probably the largest tree in the world."

A report of the international commission for the survey of the boundary-line between the United States and British North America, from the Lake of the Woods to the Rocky Mountains, has been published. The region was one hitherto unexplored by whites, and was found, as represented by the Indians, to consist mainly of swamps, making the survey a difficult one. To this were added the rigors of the climate, as the work had to be conducted chiefly in the winter, when the swamps were frozen and with the mercury at 45° below zero. The country west of the Red River would be a fine grazing-ground but for the myriad mosquitoes which drive domestic cattle almost wild and keep them from gaining flesh. In one direction the boundary-line, in the course of thirty-five miles, crossed sixty-five pieces of water, twenty-five of which were lakes, requiring a survey by triangulation. Beyond Turtle Mountain the survey was extended over the Great Plains, the Great Coteau of the Missouri, and the Salt Lakes, and the arid, desolate country known as Les Mauvaises Terres. Beginning in 1872, the survey was completed in 1874 to the base of the Rocky Mountains, where they rise from the plain in precipitous peaks 10,000 feet high. The whole boundary from the Lake of the Woods to this point is now marked by stone cairns or earthen mounds, and by iron pillars at intervals of a mile for 135 miles along the boundary of Manitoba in British America, which, it is said, "is destined to become the great granary of the Dominion." There are, however, the drawbacks of the want of markets, the ravages of grasshoppers, and the scarcity of fuel. The latter difficulty may be obviated by developing the great bituminous coal-fields of the Saskatchewan. Immigration in this direction is going on; 4,000 Mennonites from Odessa, in Russia, have settled there, and also a colony of 300 Icelanders on the western shore of Lake Winnipeg.

The arctic event of the year has been the return of the English expedition of the Alert and Discovery, under Sir George Nares, from an attempt to reach the pole by way of Smith's Sound. The vessels had great difficulty in forcing their way through Smith's Sound and Kennedy's and Robeson's Channels. They were twenty-five days making their way from Cape Sabine to Discovery Bay, a distance of only 250 miles, beset with all the perils of arctic navigation.

"Regarded from a geographical and scientific point of view, the expedition was a success. I said in my annual address, several years ago, that to reach the pole was not the main object in an arctic ex-

pedition; that that was a mere geographical feat, to which necessarily great *éclat* would be attached; but that the real object of such an expedition was to explore the arctic region in every direction as far as possible, to obtain scientific information in a quarter of the globe where it was of the highest interest—not only as respects the past physical history of the earth, but to enable us to unravel phenomena and obtain a knowledge of physical laws affecting its present condition which are of high scientific value, or, to express it in a popular form, of the greatest practical importance. This object has been to a considerable degree advanced by the English expedition. The Alert not only attained the highest latitude—82° 24′—ever reached by a vessel, and the sledge-expeditions the farthest northern point attained by man—83° 20′ 26″ north latitude—but the expedition, in an unknown region, discovered and traced a line of coast extending over nearly fifty degrees of longitude, ascertained to a considerable extent the nature of the Polar Sea bordering this newly-discovered coast, and collected a large amount of scientific information in the examination of both land and sea. A line of coast was explored 230 miles west of the spot where the Alert wintered—90 miles of which trends northwesterly to Cape Columbia, the extreme northern cape, 83° 7′ north latitude, 70° 30′ west longitude; thence westward for 60 miles to 79° west longitude, and from there gradually south to 82° 16′ north latitude and 83° 33′ west longitude, with no indication of land extending from there either westward or northward. The northeast and northern coast of Greenland was traced from Polaris Bay to a point east of Mount May in 80° 40′ west longitude, the farthest northern land seen in the expedition being in 82° 54′ north latitude and 48° 33′ west longitude (Cape Britannia and Mount Albert), and the Greenland coast was found to run from Mount May, in a southeasterly direction, to below the eighty-second parallel of north latitude; Lady Franklin's Bay, and Petermann's Fiord and its vicinity, were explored, to which must be added magnetic and meteorological and other scientific observations, and the labors of the naturalist, carried on in the winter, with the thermometer ranging at one time at 73° below zero.

"Being farther north than any former expedition, they passed an unparalleled arctic winter of one hundred and forty-two days—nearly five months—without the light and heat of the sun, and in the severest cold yet known. In the sledge-expedition of Commander Markham, in the autumn of 1875, to Cape Joseph Henry, the fall of snow was so enormous that the men had to draw their sledges through it up to their knees, and frequently up to their waists, so that, out of a party of twenty-four, twelve were severely frost-bitten, and three suffered amputation.

"In an attempt to communicate by a sledge-party with the Discovery, that vessel having wintered below in Robeson Channel, Christian

Peterson, the Danish interpreter from Upernavik, who had been Dr. Hayes's sledge-driver, became so exhausted that nothing would keep him warm. They were consequently compelled to go back with him; and the poor fellow died shortly after his return to the vessel.

"In an expedition in the following April across the Polar Sea, north in the direction of the pole, the men had not only to draw their sledges, but two heavy boats fifteen and twenty feet long, over rugged floes of ice, separated by ridges sometimes thirty feet high—to make their way over the *débris* of the pack-ice broken up by the previous summer, and refrozen during the winter into chaotic, rugged masses of angular blocks, of every possible shape. They had frequently to cut their way with picks through the hummocks; and such were the contortions and checks, that they had frequently to go five times over the same ground; so that in making a distance of 76 miles toward the pole they actually traveled over 276 miles. Each man had to drag 236 pounds, and to work from ten to twelve hours a day. They could pull but a few feet at a time, and make but from one mile and a quarter to two miles and three-quarters a day. They were absent on this sledge-expedition, engaged in this incessant labor, for two months and a half; and, to add to their trials, the scurvy broke out among them, so that, when relief reached them, out of the seventeen of the party only five were able to drag the sledges. The sledge-party along the north coast of Greenland were beset with like difficulties. Enormous blocks of polar ice had been pressed against the shore, making the traveling one of incessant labor, so that seven days were occupied in moving only twenty miles. The scurvy also broke out with them; and, when they came in, two only were able to draw the sledges. The western sledge-party found the same heavy ice extending along the whole coast. They were also attacked by the scurvy, Lieutenant Aldrich being the only one who escaped; and relief fortunately reached them the last day that most of them were able to travel. . . .

"The return of the expedition, and its results, have given rise to a great deal of discussion, both in this country and in England. Sir George Nares is of opinion, and Dr. Petermann in a recent letter concurs with him, that any further attempt to reach a higher latitude by the way of Smith's Sound is hopeless, and that any future effort must be by the route between Spitzbergen and Nova Zembla. I fully agree in the correctness of this judgment, so far as respects any attempt to get farther north by the way of Smith's Sound in a vessel. I have never found sufficient facts to lead me to believe that there is an open polar sea that can be reached by a vessel, nor any physical reasons why there should be a great space of open water at the pole, or in its vicinity. This belief is a very old one. The supposed sea is to be found represented upon a map published 268 years ago. There may be such a sea. The knowledge we possess will not warrant the assumption that it does not exist; but it will warrant this statement—

that the more we become acquainted with the area of the polar basin, and the nearer we get to the pole, the fewer indications there are of the existence of such a sea. I am not, therefore, very hopeful that any vessel will be able to get much farther north than vessels have already attained; but I do believe, notwithstanding the result of the English expedition, that the polar area can be traversed much farther north in that direction by sledging, and that it can be done by the way of Smith's Sound as effectually as between Spitzbergen and Nova Zembla. The plan which Dr. Hayes laid before this Society eight years ago, of establishing a station at Fort Foulke, where subsistence can be easily obtained, and with which communication can be regularly kept up by sea, as a base from which expeditions may be directed to the north as favorable opportunities offer, I have always thought the best plan of polar exploration, and for many reasons preferable to sending out large expeditions. It would not require a large force, would afford opportunity for the training and experience in the arctic regions, which is requisite, and could be kept up at a comparatively small expense. Captain H. W. Howgate, of the United States Signal Service, has recently called public attention to a plan substantially of this character, and a bill embodying his suggestion is now before Congress, to establish a temporary station for the purpose of exploration at some point north of 81° north latitude, on or near the shore of Lady Franklin's Bay; and Captain I. L. Norton, a shipmaster, who has had some experience in the Antarctic, is maturing a like plan, which, he advises me, he will lay before this Society."

The several surveys instituted by our Government across the American Isthmus to ascertain the most feasible route for the construction of an interoceanic ship-canal have been completed, the result showing that the Nicaragua route is the most practicable. It will take ten years, at least, to construct it, and the cost is estimated at about $10,000,000.

"A cavern has been found in Cuba containing Carib remains, indicating that the whole of that island was formerly inhabited by the Caribs.

"Prof. Weiner has been occupied during the year in ethnological researches in South America, and reports from Pacha Camac that he has discovered glaciers in the Andes and Chili, which had been questioned by Agassiz; and Prof. Hartt, chief of the Brazilian survey, is reported to have recently made important geological discoveries in Brazil. The Government of Brazil has undertaken the measurement of an arc on the parallel of 23° south latitude, extending over nine or ten degrees of longitude, connecting the capital of the country with the great meridian of Brazil.

"The Amazon is now navigated by steamers 3,000 miles from its mouth, and several of its tributary rivers have been opened up to steam-navigation. I would especially call attention to the great com-

mercial importance to the United States of direct and regular communication from this country by steam with the mouth of the Amazon, in view of the importance of the regions of the Upper Amazon and its tributaries, which are now made accessible by steamers."

In Europe initiatory steps have been taken for the measurement of an arc of the meridian parallel with Algeria. The surveys in Austria have been actively prosecuted; 2,066 square miles have been surveyed in Galicia and Hungary, and 200,000 altitudes determined. The whole of the Tyrol, the greater part of Transylvania, and parts of Lower Austria and Bukowina, have been mapped. Surveys in Turkey and Greece promise at an early day a good map of the Balkan Peninsula. Deep-sea soundings have been made between Norway, the Shetlands, the Faroes, Iceland, and East Greenland.

The Russians and others have been active during the year in Asia, in the regions around the White Sea, in the country of the Caspian, the Altai and trans-Altai Mountains, the northern part of Pamir, in the lower part of the river Obi, upon the Irkoort River, from Wjernga to Kashgar, in the valley of Fergani, of the Shueli, and in the western part of the Chinese province of Yunnan; also in East and Northwest Mongolia, between the Himalayas and the Tian-shan, China, and Turkistan, in Japan and Siam, and the river Mekong in Cochin-China. The Siberian coast has been surveyed between parallels 45° and 52° north latitude; the soil is good, vegetation luxurious; lead, copper, gold, silver, and coal, were found.

The German Arctic Society, in pursuance of a plan for polar research, "dispatched an expedition which last July reached Obdorsk, the most northern settlement on the river Obi, where they met the Russian expedition, organized for the survey of the rivers Bar and Chuca, that flow into the sea of Kara, and the course of the river Obi, to determine the possibility of connecting these rivers with a canal. Thence the party made their way to the Kara Sea, a very difficult route; and, upon their return last autumn, they passed through the Kara Sea and the strait without any impediment from the ice, and have transmitted a very interesting account of their journey in Siberia. Prof. Nordenskiöld has again passed safely into the Kara Sea and to the mouth of the Yenisei, and has already returned. He found the Kara Sea free from ice in September, and declares that the navigability of the Yenisei is now ascertained, and is confident that a trade-route may be established to that river through the Kara Sea."

In Thibet, in Japan, in Siam, and in Persia, extensive explorations have been made. The great survey of India is going on at the rate of 40,000 square miles per annum. The American Palestine Exploration Society has suspended work, in accordance with the advice of the advisory committee in Beyrout, partly because of the disturbed condition of Turkey, and the continued commercial depression at

home. The engineers have, however, made a rapid reconnoissance of nearly the whole territory east of the Jordan.

"I have frequently called your attention to the remarkable remains that are found in the country east of the Jordan—the Moab Bashan Gilead of the Bible—of which, until the recent explorations, nothing comparatively was known. Though this part of Syria may be reached in a few days from the northern part of the Dead Sea, or from the sea of Galilee, it was not visited by travelers, in consequence of the rugged nature of the country and the hostile tribes of Bedouins that inhabit it. It has now been ascertained to abound in architectural and archæological remains of the greatest interest. It is literally strewed with the remains of towns and of structures, many of them remarkable for their massiveness, which belong to a past civilization, of which we know nothing. You will remember that some years ago, from the indications which then existed, I expressed the opinion that this must have been, at an early period, one of the chief routes between Asia and Africa, and the ruins which have since been found in the explorations carried on by the American society, and their extent, confirm that impression.

"Dr. William Thompson, the veteran American missionary and explorer in Syria, in a recent letter says that, in making a tour through this region, nothing ever impressed him so much as the richness of this field in the remains of ancient civilization. He says that there are not only acres on acres of splendid ruins, but fortifications, temples, baths, and theatres, the best preserved in existence, and which have evidently stood undisturbed for ages. While on the west side of the Jordan, he remarks, cities have been robbed to build other cities—just as the ruins of Tyre are now contributing ship-loads of stone toward building the present city of Beyrout—the east side of the Jordan has remained unmolested for 1,500 years; and that there exists there an unequaled combination of art and Nature in an untouched condition of splendor and ruin."

The work of exploration and investigation in respect to the unknown parts of Africa has been vigorously followed up during the year. The Niger, Volta, Ogowe, and Congo Rivers have been explored more or less fully. The source of Guango River has been reached by penetrating the interior across the Talamunga Mountains, which are from 4,000 to 5,000 feet high.

"When our fellow, M. du Chaillu, several years ago laid before us the account of the pygmies he had found in Western Africa, near the equator, it was received in certain parts of Europe with incredulity; but these pygmies of the western coast have since been seen by others, and the existence of races of pygmies is now established by the facts gathered by Schweinfurth, Miani, and others in Africa, and by recent researches in India. Mr. Marcette says that these pygmies were well known to the ancient Egyptians, and that there is a bass-

relief, in the sepulchre of the Necropolis of Saggarale, of the fifth dynasty, upon which two pygmies are represented, having the features of Dr. Schweinfurth's Akka. He says the pygmies of antiquity were natives of Pun, which he indentifies with the modern Somali country. The Phœnicians came from Pun, and were not an Asiatic race, and near them dwelt a race of dwarfs called Bess, who still exist in the Somali country."

The district of Akem, in the north portion of Ashantee, has recently been visited. The country is fertile, heavily wooded, well watered, and highly auriferous. "The climate is humid throughout the year; the men are capable of undergoing great fatigue, but are incorrigibly idle, and the women do all the work. Among the men he found an extraordinary growth or enlargement of the cheek-bones under the eyes. It is in the form of horns on each side of the nose, and so long that in some instances the man had to squint violently to see at all. The growth begins in childhood. The skin is not broken, but stretches over the horns like a glove. This phenomenon he thought peculiar to the tribe in Akem, as he did not find it in any other. Photographs of these horned men, it is said, have recently been received in England."

The circumnavigation of the Mwutan Nizigi (Albert Nyanza) is the important event of the year in Africa, establishing the connection between this lake and the Nile. It appears that the White Nile is navigable the whole way from Dufli to the lake, a distance of 164 miles. About 100 miles from Dufli there is a large branch of the river, extending north-northeast in the direction of the Nyam-Nyams. The country east of the lake has also been explored, and a chain of military posts established from Gondokoro to both Mwutan Nizigi and the Ukerewe (Victoria Nyanza). The Somerset River was reached, and a station established at Masuidi, the capital of Unyora. The Somerset Nile, which connects the two lakes, is navigable from Mwutan Nizigi to Murchison's Falls; but from there to the Karuma Rapids it abounds in swift water, having a fall of 700 feet between Murchison's Falls and Foueira.

Mr. Stanley, after exploring Lake Ukerewe, crossed the country of Unyora to the Mwutan Nizigi, reaching that lake at a point where a deep gulf (Beatrice Gulf), formed by a promontory called Unsongora, runs out for thirty miles in a southwesterly direction. The position of his camp on the lake is 31° 24′ 30″ east longitude, and 25′ north latitude. The country of Unyora extends along the eastern shore; that on the south shore is called Ruanda. On the west, opposite Gulf Beatrice, is Ukonju, peopled by cannibals, and the farther western shore to the north is the country of Ulegga. The people of the south and southwestern shores were very hostile. Stanley followed up the course of the Kitangule River, the main feeder of Lake Ukerewe, and circumnavigated Lake Windermere of Speke; and afterward, on

the frontiers of Karewega, found Lake Akengara, noted in Speke's map. When last heard from, in July, he was on his way to Unamyembi, intending to explore Lake Tanganyika, and then strike northward to the Mwutan Nizigi. Commander Cameron's journey is claimed to have settled the line of the Central African lake-sources. The chief products of Central Africa are ivory and slaves. Westward from Katanga there are large copper-mines; coal, cinnabar, and tin, were found; sugar-cane, rice, wheat, cotton, and hemp, grow well; the vegetable and mineral products would make the people of Africa industrious and prosperous, were they not ruined by the slave-trade. The way to stop this traffic is to open up the rivers Congo and Zambesi, for there is a way across the continent by a system of water navigation second to none in the world. A missionary station has been established on Lake Nyassa, in memory of Livingstone, with a view to the suppression of slavery, and every friend of humanity will unite in wishing success to this philanthropic endeavor which Livingstone had so deeply at heart. A way has been found from Zanzibar to the interior highlands which is free from the fever-swamps of the old route, and also from that great scourge of East Africa, the tsetse-fly, a fact of great importance in opening up Central Africa.

An Italian expedition started last February, for the exploration of the country on the east coast between Shoa and Lake Ukerewe. After many hardships, Liece, the capital of Shoa, has been reached, which will be made the base of a scientific exploration of the lakes. The expedition is to be absent four years.

"I regret exceedingly to hear of the recent death of Mr. Rebman, the well-known missionary, who first suggested the existence of a system of lakes in Central Africa, which was verified by the discoveries of Burton, Speke, Grant, Baker, Livingstone, Long, and Stanley."

There is little to record in regard to South Africa. The diamond-fields of the Orange Free State and the gold-fields of the Transvaal Republic have not only attracted the enterprising and industrious, but have also excited the cupidity of their English colonial neighbors, in a way which it is feared will prove anything but beneficial to the rising African republics.

During the last five years the great island of New Guinea, which thirty years ago was put down as an unknown land, has been the scene of active explorations. The country has been penetrated by way of Baxter and Fly Rivers for 90 and 150 miles respectively. It is peopled by a mixed race, Malayan and Papuan, brave and energetic, speaking different dialects, and at war with each other.

The country watered by the Baxter River is low, swampy, covered with forests of mango-trees and thinly populated, contrasting in this respect with the Fly River, which swarms with human beings. The Malayan population of the eastern shore are far above the savage,

and are opposed to the polygamy and cannibalism which exist among the Papuans. The southern peninsula of New Guinea was explored; a range of mountains forms the backbone, running north and south; at a height of 4,000 feet were found dense forests of tropical vegetation, covering the whole northern range except the top of Mount Owen Stanley, which rises in a double peak 13,205 feet. The soil of this region is very rich; sugar-cane, yams, sweet-potatoes, and tobacco, are cultivated; bread-fruit and mango are indigenous. The people have frizzled hair, and are darker than the Malays, differing from them also in disposition, being inoffensive and friendly. "The women take an active part in any disturbance, and were found more capable of making a hard bargain than the men. None of the tribes believe in a God, and attribute everything extraordinary to some supernatural agency.

"The climate of this part of the peninsula is relaxing. It is impossible to live in the valleys without impairing the constitution, from the excessive moisture; but in the interior it is more salubrious. Birds are very numerous, conspicuous among which is the bird-of-paradise, but flowers are scarce. Miclucho Maclay, who has made extensive explorations in New Guinea, was engaged last July in explorations on the northeast side of the island, about Astrolabe Bay, the part of the coast which has been named after him; and he reports that in April an earthquake occurred in the highlands in that vicinity, which destroyed many villages."

The island is 1,400 miles long, and from twenty to 450 miles wide; it possesses great vegetable and mineral wealth, and large portions of it are suitable to European colonization. It may in the future become the seat of an important civilization.

"The islands of the northeast coast of New Guinea have been visited. The natives are nude savages of the Oriental negro type, who live more like beasts than human beings. Cannibalism prevails throughout the islands, not as a religious rite, but as a means of subsistence. The details of this horrible practice are too revolting to repeat. The natives say that there is in the islands a race of human beings with tails, who are not monkeys; that the tail is bony and inflexible, so that those with this caudal appendage have to dig a hole in the sand before they can sit down, as they die if the tail is broken. We have thus revived the account of the men with tails heretofore reported to exist in Borneo and the interior of Africa, but always upon native information, with the exception of hearsay information alleged to have been given by a sailor cast away on the coast of Borneo, and, like all such, of little value."

Exploration has been made of that portion of the Australian Continent lying between Murchison and the Overland Telegraph line. The Ashburton River was traced to its source, thus defining the extent and position of the western water-shed which abuts on the

desert in 120° 20′ east longitude. No water-courses were found flowing to the eastward; along the twenty-fourth parallel to 127° east longitude, the country was found to be an open desert.

"This very imperfect survey of the geographical work of the world, when regarded as the work of a single year, justifies, I think, what I said in my last address—that we are living in a great geographical age."

IS THE MOON A DEAD PLANET?[1]

IT is not a little curious that the great body which for ages has been proverbial for its changeableness should have at last come to be looked upon as the most unchangeable of bodies. When the earth was regarded as constituting the universe, and the heavenly bodies as mere exhalations from it, the moon was, of course, believed to be nothing but a meteor—a great lantern hung in the sky to illuminate and rule the terrestrial night; but, when modern astronomy had established the idea that the earth is but a moving planet, and the planets themselves great orbs like our own globe, speculation inevitably arose in regard to their condition. It was then concluded that the moon may be like the earth, with its oceans, plains, mountains, atmosphere, vegetation, and inhabitants; and this idea long prevailed as a part of the great doctrine of the plurality of worlds. But an opposite opinion at length grew up among astronomers, which has been greatly strengthened in recent years. This change of view has been largely ascribed to the celebrated astronomer Mädler, who made a very forcible statement of the differences and contrasts between the condition of the moon and that of the earth, and pointed out that the current view that the moon may be a copy of the earth is impossible. These views crept into astronomical text-books, and gradually led to the conviction that the moon is a sort of played-out or defunct planet, destitute of air and life—a mere mass of rocks and cinders, cold, lifeless, and unchangeable.

But although this view is still current among astronomers in general, there is a class of astronomers (selenographers, as they are called) who have studied the lunar surface with long and profound attention, and to whom we are indebted for our present knowledge of our satellite, who hold a different view. They agree in the belief that many processes of actual lunar change are in progress, and they have detected the existence of a lunar atmosphere. This conflict of opinion is said to be due to the fact that the labors of selenographers are in-

[1] Abridged from an article in the *Quarterly Journal of Science*, entitled "Physical Changes upon the Surface of the Moon," by Edmund Neisan, F. R. A. S., author of "The Moon, and the Condition and Configuration of its Surface."

accessible to most astronomers, and are hence but imperfectly known. The inquiry, we are told, is one of great difficulty, requiring a thorough acquaintance with several branches of science. The results arrived at by prolonged, minute, and careful observation of the details of the lunar formation are rejected because the proofs on which they rest are not well understood.

The most prominent instance of supposed lunar change on the surface of the moon is that of the crater Linné. On the northwest quadrant of the moon, near the centre of a level tract about 430 miles in diameter, there is a bright crater called Bessel, nearly 14 miles in diameter, with a circular wall rising 4,000 feet above the interior, and about 1,600 feet above the surrounding plain. Scattered over this plain are a few small craters, some $2\frac{1}{2}$ miles in diameter, with walls about 300 feet high. Near its eastern centre an eminent selenographer named Lohrman placed a distinct, bright crater about five miles in diameter, which he described as being, after Bessel, the most conspicuous object on this great tract of level ground. Ten years later, our greatest selenographer, Baron von Mädler, confirmed Lohrman's observations, and made this crater a subject of special study, naming it Linné. In the drawings of Schmidt, who was about this time making lunar observations of this particular part of the moon, Linné is shown as a deep crater corresponding with the descriptions of Lohrman and Mädler.

In October, 1866, when Linné was in a position to be most conspicuous, Schmidt was startled by finding no trace of the deep, wide crater, but only a faint cloud marking about five miles in diameter. Schmidt at once announced the circumstance, and nearly every astronomer in Europe turned his attention to the spot. But Linné has never since been seen of the size and character given it by Lohrman, Mädler, and Schmidt. This large crater unquestionably no longer exists. Powerful telescopes reveal, in its place, a white, cloudy marking containing a small crater-cone with an opening scarcely one-twentieth the size of the former crater.

The reason why astronomers will not admit the reality of any change in Linné is, first, a strong prejudice against the possibility of such change; and, second, the fact that Schröter, of Lillienthal, the earliest of the great selenographers, in one of his first drawings, made November 5, 1788, with low powers, does not draw Linné as a crater. Near its place he draws a white spot on a ridge marked V, and a larger spot marked G. Schmidt took this white spot to be Linné, a view strongly urged by Huggins, and accepted as correct by astronomers. They say, as Schröter's drawing is not unlike the present appearance of Linné, Lohrman, Mädler, and Schmidt, must have been mistaken as to what they thought they saw. Again, in a map made by Lahire in the seventeenth century, no trace of Linné can be found. It may be said, however, that all the maps of this period

omit numerous craters far larger than Linné. They were principally full-moon drawings, where Linné would not be visible as a crater. Riccioli's map, however, shows Linné as a distinct crater. But the present crater on the site of Linné could not possibly have been seen by Riccioli with the optical means at his command.

In every other instance of discrepancy between the drawings of Schröter, and Beer, and Mädler, Schröter's are rejected, while in this particular case one of Schröter's earliest drawings, made with imperfect instruments, is brought forward to prove the incorrectness of his great successors.

It will require long study of this region with powerful telescopes to determine the nature of the change undergone by Linné. From numerous observations the explanation agreeing best with the present condition of the surface is, that the walls of the old crater have collapsed and fallen into the interior. In this way the interior would be almost entirely filled up, leaving a rough, cone-like crater in the centre. Under favorable conditions, with a powerful telescope, the surface immediately around the small crater appears rough and irregular. Round the border of the old crater are numerous mounds and blocks, and on the east, one or two peaks or low hills, seeming like portions of the old wall. The difficulty of making these observations is very great, and they are only possible in the finest atmospheric conditions.

Proctor has tried to show that the changes in Linné are variations of tint due to differences of illumination. But no selenographer will admit that any alteration whatever in illumination could make an object where Linné is placed, look at one period like a considerable and deep crater, and at another as a small, scarcely visible crater.

The facts about Linné may be therefore summed up very briefly. According to three or more independent selenographers, the most experienced that science has seen, the object named Linné was a conspicuous crater of large diameter and great depth. Now, in its place all that exists is a tract of uneven ground, containing a small, scarcely visible, insignificant, crater-like object. It is impossible that one could ever be systematically taken for the other. It is inconceivable how our three greatest selenographers could have systematically and independently made the same blunder, and that one blunder only. For in no other case do we find any error of this nature. Their description must, therefore, be held to truly describe the nature of the formation at their epoch (1820–'45). The object is no longer of the same size and description. A real physical change on the moon's surface must therefore have occurred at this point. This, then, is the conclusion that selenographers as a body have arrived at; yet, despite the strong evidence on which it rests, it is not generally recognized by astronomers.

The next instance of change on the surface of the moon is that of

the crater named Messier by Beer and Mädler. In its equatorial region, on the westernmost of the great lunar plains, close to one another, are two small crater-plains about nine miles in diameter, surrounded by very low ridges and mounds and crater-like depressions. These two formations, named Messier and Messier A, were discovered and described by Schröter, who regarded Messier as slightly the larger. Beer and Mädler examined these formations most carefully on more than three hundred distinct occasions between 1829 and 1837. They declared that the two crater-plains were exactly alike in every particular. Both were circular and of the same size, with bright, grayish-white walls and a yellowish-gray interior. The walls were of the same height, with wall-peaks situated in the same relative position. In diameter, form, height of walls above the surrounding surface, and depth and color of the interior of the walls, Beer and Mädler declared that they were completely alike. Some years after this, a slight dissimilarity between the forms of the two craters was noticed, and in November, 1855, the Rev. T. W. Webb, one of the best living lunar observers, discovered that the eastern crater-plain, Messier A, appeared the larger of the two.

In March of the following year he observed that not only was Messier the smaller, but that it was elliptical. He confirmed these observations on repeated occasions, and in 1857 made drawings showing Messier A unchanged, while Messier had an elliptical form, with a long diameter of about 10 or 11 miles and a short diameter of about $7\frac{1}{2}$ to 8 miles. The matter attracted little further attention until 1870 to 1875. During these years Messier and Messier A were studied with the aid of powerful telescopes, and during the past year the long diameter of Messier appears to be 12.2 miles and the short diameter 6.9. The difference between the form and dimensions of these two formations is now obvious in the smallest astronomical telescope. It is inconceivable that Beer and Mädler could have failed to recognize these differences with their fine Fraunhofer equatorial, with which, on hundreds of different occasions, they carefully scrutinized them in search of differences.

This slow squeezing out of shape of an immense crater-plain is a change that seems to defy explanation. Nothing analogous now exists on the surface of the earth, and it is not surprising that there should be a strong reluctance to admit that such a change has occurred. A careful examination of Messier and its neighborhood, however, suggests that, instead of a bodily compression of the entire crater, there has been a gradual sliding of the north and south walls into the interior, and a pushing of the entire western wall outward and westward down an incline existing there. Selenographers could point to a hundred cases where a like circumstance has occurred. As far as is at present known, this explanation accords with the condition of the formations around Messier, but further observations with

powerful telescopes are indispensable. Unfortunately, it is a difficult matter to study, for on only one or two days in the year is Messier likely to be found in a proper condition to be observed.

Other instances of change in the lunar surface have been detected by selenographers, but the evidence on which they rest is not so overpowering as is needed to induce their acceptance.

Periodical variations in the color and brightness of lunar regions, such as would result from processes of vegetation, were first noticed by Beer and Mädler, but they regarded the absence of masses of water upon the moon as a fatal objection to this explanation. The variation in the floor of Plato is one of the most interesting of these changes. Plato is a circular plain 60 miles in diameter, surrounded by a belt of highlands from 3,000 to 3,500 feet in height. These highlands at sunrise are a pale yellowish gray, gradually changing to grayish white. At sunrise the interior of Plato appears of a cold gray, but, as the sun rises higher above the horizon of Plato, and the solar rays fall more perpendicularly on this region, the whole surface grows rapidly brighter, until, about two days after sunrise, the interior of the formation attains its brightest tint. It is then a cold, light yellow gray, often approaching a pale yellow, in fact, and brighter than the surface of the Mare Imbrium on the north, while the surrounding highlands are a bright grayish white, tinted here and there with gray. Judging from what occurs in any of the numerous other formations resembling Plato, this may be considered the normal tint, inasmuch as those other formations which present exactly the same phenomena up to this time, and which, under similar conditions, present exactly the same appearance, retain this tint unaltered until near sunset. After, however, the second day, the floor of Plato commences to undergo a most extraordinary and anomalous change, which renders it unique on the moon, for, instead of growing lighter, the interior commences to become darker. Four days after sunrise it is materially darker than the northern Mare, and a cold gray in tint, while the surrounding highlands are a bright white in color, tinted with gray; the appearance they retain until the thirteenth day after sunrise, growing a little, though not very much, brighter toward full moon. Two days later the floor of Plato has become a dark gray; at full moon it is deep steel-gray; and, about two days after full, reaches its darkest tint, a very deep steel-gray, almost approaching a black color. Under these conditions, it is one of the very darkest portions of the entire lunar surface, though, seven days prior, it was one of the lightest portions of the surface of its kind. After this, it gradually lightens in tint, but much slower, and never reaches so light a tint.

This extraordinary periodical change in the tint of the floor of Plato has hitherto received no explanation, but its existence has been put beyond the pale of doubt, and Mr. Birt has, at the instance of a British Association Committee, carefully discussed a numerous series

of observations, made in the years 1869, 1870, and 1871, by six or seven independent observers.

Proctor has attempted to show that these appearances are the effect of contrast. Thus, at sunrise, the floor of Plato is thrown against a dark background, due to the sombre, barely-illuminated surrounding regions; while at full moon it has for a background the brilliantly-illuminated surrounding highlands, and should look much darker. But if the great darkening observed to occur in the tint of the interior of Plato is merely apparent, and only what must occur when a darkish walled plain is surrounded by a bright background, or, rather, bright environs—and this is all Mr. Proctor ascribes to it—it must be a perfectly normal occurrence, and the same must take place in every similarly-placed formation, unless that has something anomalous about it to prevent this taking place. All selenographers could instance a number of such walled plains where no such darkening occurs. Are we, then, to assume that these plains possess anomalously constituted interiors, and that only Plato, of all the lunar formations, exhibits the normal phenomena? This is, of course, entirely inadmissible, and selenographers are thoroughly aware that the effects of contrast alluded to by Mr. Proctor are entirely incapable of bringing about such an immense darkening in tint as is apparent in the case of the floor of Plato.

The reason of this singular darkening in the floor of Plato is not yet understood. Selenographers believe that it results from an actual change due to the heating action of the solar rays. But the further elucidation of the subject requires special observations with special appliances. Thus, as in so many selenographical problems, patient observation establishes the existence of certain phenomena, but the elucidation of the meaning of the phenomena established is checked for want of special observations that are never made. For these, selenographers have to appeal to those astronomers devoted to what has been termed astronomical physics, but they are too much engaged on more fascinating subjects to give attention to such inquiries.

The instances here dealt with will show that selenographers are not without strong evidence in favor of the opinion that has long been unanimously held by them, that processes of change are still actively at work upon the moon. It must not, however, be supposed that the above are the sole instances which they have recognized, because this is by no means true, only the difficulties in establishing others have led to their omission here. Dealing with a subject such as selenography, it is only those who are familiar with all its details who properly appreciate the evidence in favor of or against its problems. The difficulties in the way of making the true bearings of selenographical questions properly understood are greater than might be imagined; for even the very elementary fact that volcanic changes such as are now active on the earth would not be recognizable on the moon, in

the present state of our acquaintance with the configuration of its surface, is not generally understood. When, however, the attention of astronomers is more generally directed to the study of the lunar surface, Science will be greatly the gainer, as it is there that the past and future of our earth is to be learned.

SIZE OF THE PRINCIPAL TELESCOPES IN THE WORLD.

IN *Les Mondes*, January 20, 1876, appeared a list of the principal telescopes of the world, with their apertures and focal lengths. It was defective in regard to its enumeration of American telescopes, and in other respects, as all such lists must be. We have compiled from it, and from other sources available, a larger list, which is itself manifestly incomplete, but which will give a better idea of the number of telescopes available, or soon to be available, for astronomical purposes. It is a melancholy fact that the return from so many instruments, that is, the interest from so much astronomical capital, is not so great as it should be, and it suggests the question as to whether future benefactors of American colleges, for example, will not do better to provide astronomers to use the telescopes already constructed than observatories in which to put new ones. In the second column, the first name is that of the maker of the objective or speculum, the second that of the engineer who mounted the telescope.

I. Reflectors.

One French inch = 12 Paris lines; one English inch = 11.26 Paris lines; one metre = 443.30 Paris lines.

OWNER OR DIRECTOR, AND OBSERVATORY.	Constructed by	APERTURE.			FOCAL LENGTH.			REMARKS.
		English Inches, etc.	French Inches.	Metres.	English Feet, etc.	French Feet, etc.	Metres.	
Lord Rosse, Birr Castle.	Rosse	6 ft.	......	......	55 ft.	......	......	
Wm. Herschel, Slough	W. Herschel	4 "	......	......	40 "	......	......	Out of use.
Lassell, Liverpool, etc.	Lassell	4 "	......	......	37 "	......	......	Destroyed.
Ellery, Melbourne	Grubb	4 "	......	......	32 "	......	......	
Le Verrier, Paris	Martin, Eichens.	......	......	1.20	......	......	7	Silvered glass.
Lord Rosse, Birr Castle.	Rosse	36 in.	......	......	......	......	......	
Tisserand, Toulouse	Foucault	......	......	0.80	......	......	......	Silvered glass.
Stephan, Marseilles	Foucault, Eichens	......	......	0.80	......	......	4.80	Silvered glass.
H. Draper, near N. York.	H. Draper	28 in.	......	......	13 ft.	......	......	Silvered glass.
Lassell, Maidenhead	Lassell	24 "	......	......	20 "	......	......	Metal.
W. & J. Herschel, Slough, and Cape Good Hope	W. & J. Herschel	18 "	......	......	20 "	......	......	Several mirrors.
H. Draper, near N. York.	H. Draper	15 "	......	......	......	......	......	
Maclean, Tunbridge Wells	With & Browning	15 "	......	......	......	......	......	
Pritchard, Oxford	De la Rue	13 "	......	......	10 ft.	......	......	
Worthington and Baxendell, Manchester	With & Browning ?	13 "	......	......	......	......	......	
Hirst, New Zealand	Browning	$8\frac{1}{2}$ "	......	......	......	......	......	Silvered glass.

and many others.

II. Refractors.

Owner or Director, and Observatory.	Constructed by	Aperture. English Inches.	Aperture. French Inches.	Aperture. Metres.	Focal Length. English Ft. and Inches.	Focal Length. French Ft. and Inches.	Focal Length. Metres.	Remarks.
Lyman, Yale College	A. Clark & Sons.	28						Constructing.
Littrow, Vienna	Grubb	27						Constructing.
McCormick, ?	A. Clark & Sons.	26¼			33 ft.			
C. H. Davis, Washington.	A. Clark & Sons.	26			390 in.			
Newall, Gateshead	Cooke	25			29 ft.			
Buckingham, London	Buckingham	21						
University of Chicago	A. Clark & Sons.	18.5			23 ft.			
Winnecke, Strasburg	Merz		18					Constructing.
Pickering, Harvard Coll.	Merz	15			23 ft.			
O. Struve, Pulkova	Merz	14.93			270.6			
Lord Lindsay, Dun Echt.	Grubb	15			15 ft.			
Huggins, London	Grubb	15						
Downsede College, Bath.		14.5						Destroyed by fire in 1867.
Cooper, Markree Castle	(?)	14			25 ft.			
Oom, Lisbon	Merz		14					
C. H. F. Peters, Clinton.	Spencer	13.5			16 ft.			
Boss, Albany	Fitz	13			182 in.			
Rutherfurd, New York	Rutherfurd	13						Photographic.
Langley, Pittsburg		13						
Watson, Ann Arbor	Fitz	12.5			17 ft.			
Airy, Greenwich	Merz & Simms	12.5			16.6			
Mitchell, Vassar College.	Fitz, reworked by Clark	12.33						
Pritchard, Oxford	Grubb	12.25						
Pritchett, Glasgow, U. S.	A. Clark & Sons.	12.25			17 ft.			
Le Verrier, Paris	Secretan & Eichens		12				5	
Littrow, Vienna	A. Clark & Sons.	12						
Adams, Cambridge	Cauchoix	12			20 ft.			
Ball, Dublin	Cauchoix	12 ?	12 ?					
H. Draper, near N. York.	A. Clark & Sons.	12						
Main, Oxford	Cauchoix	12 ?	12 ?					
Pritchard, Oxford	Grubb	12						
Le Verrier, Paris				0.32				
White, Brooklyn	Fitz, reworked by Clark	11⅞						
Stone, Cincinnati	Merz	11.5			17 ft.			
V. Bülow, Bothkamp	Schroeder		11			16		
Lamont, Munich	Merz		10.5			15		
Schjellerup, Copenhagen.	Merz		10.5			15		
Gould, Cordova	Fitz	11.25			14 ft.			Photographic.
Van Vleck, Middletown, U. S.	A. Clark & Sons.	11						
———, Florence	Amici		11					
Oom, Lisbon	A. Clark & Sons.	11						Photographic.
Rutherfurd, New York	Rutherfurd and Fitz		10.5					Photographic.
D'Aguilar, Madrid	Merz		10					
Bredichin, Moscow	Merz, reworked by Clark		10			16		
Michie, West Point	Fitz, reworked by Clark	10			14 ft.			
Stephan, Marseilles	Eichens			0.25			3	
Barclay, Leyton	Cooke	10			12 ft.			
Fletcher, Cumberland		10			12 "			
———, Dorpat	Fraunhofer	9.62				14		
Förster, Berlin	Merz	9.62				14		
Secchi, Rome	Merz	9.62				14		
Tacchini, Palermo	Merz	9.62				14		
Kowalski, Kazan	Merz	9.62				14		
C. H. Davis, Washington.	Merz, reworked by Clark	9.62						
Lefont, Calcutta	Steinheil	9.62			172 in.			
Pogson, Madras	Lerebours and Secretan	9	9 ?					
Buckingham, London	Secretan	9	9 ?					
Young, Dartmouth	A. Clark & Sons.	9.38			12 ft.			
Grant, Glasgow		9						
Crossley, Halifax	Cooke	9.33						
Edgecomb, Hartford	A. Clark & Sons.	9.4	9					
Schultz, Upsala	Steinheil							
Barneby, Worcester	Cooke	9						
Bruhns, Leipsic	Steinheil, Pistor.		8			12		
Menten, Quito	Merz		9			117		

II. Refractors—(*Continued*).

OWNER OR DIRECTOR, AND OBSERVATORY.	Constructed by	APERTURE. English Inches.	French Inches.	Metres.	FOCAL LENGTH. English Ft. and Inches.	French Ft. and Inches.	Metres.	REMARKS.
Stonyhurst College		8						
Wilson, Rugby	A. Clark & Sons.	8.25						
——, Florence	Amici		8					
Erck, Ireland	A. Clark & Sons.	8				75 in.		
Ashe, Quebec	A. Clark & Sons.	8				9 ft.		
Hartnup, Liverpool	Merz	8			12 ft.			
Lyman, Yale College		8.25						
U. S. Naval Academy	A. Clark & Sons.	7.75						
Esty, Amherst College	A. Clark & Sons.	7.25			101 in.			
Bishop, London	Dollond	7			11 ft.			
Knott, ——	A. Clark & Sons.	7.33			9.4			
Birt, London		7.5						
Leeson-Prince, ——	Tulley	7			12 ft.			
Russell, Sydney	Merz	7			9.66			
Main, Oxford	Repsold	7.5			10.5			Heliometer.
Williams College, U. S.	A. Clark & Sons.	7 1/8						
——, Naples	Fraunhofer		7					
O. Struve, Pulkova	Merz		7					Heliometer.
(Col'ge), Shelbyville, U.S.	Merz		7		10 ft.			
Hansteen, Christiania	Merz		7					
Kaiser, Leiden	Merz		7					
Dembowski, Florence	Merz		7					
Russell, Sydney	Merz		7					
Luther, Königsberg	Fraunhofer and Merz		70.2 l.			1,134 l.		Heliometer.
——, Capstadt	Merz		6 5					
Wendell, Bates College, U. S.	A. Clark & Sons.	6.25						
Moore, Lynn, U. S.	A. Clark & Sons.	6.25						
Burnham, Chicago	A. Clark & Sons.	6						
Lee, Hartwell	Tulley	6						
Lockyer, London		6.25			8.5			
Monckhoven, Genth	Cooke	6			7.5			
Lord Lindsay, Dun Echt.	Cooke	6			6			
——, Madras	Dollond	6 ?			5			
Wolf, Zürich	Dollond	6	6 ?			8		
Schmidt, Athens	Dollond	6	6 ?					
Schoenfeld, Bonn			6					Heliometer.
Moesta, Santiago	Young, Fitz		6.4			103.7		
High School, Philadelphia	Merz		6			8 ft.		
Trouvelot, Cambridge	Merz		6			8.5 ?		
Peck, Columbia College	A. Clark & Sons.	6						
Durham University	Ross	5						
——, Lucknow	Troughton	5.5						
Broun, Trevandrum	Dollond	5			7.5			
U. S. Transit Venus Com.	A. Clark & Sons.	5			5 ft.			8 instruments.
Loomis, Yale College	Dollond	5			10 "			
Curley, Georgetown	Simms	5			80 in.			
Pickering, Harvard Coll.	Merz		4		5 ft.			
Luther, Bilk			4					
Tebbutt, New S. Wales		4.5						
Bruhns, Leipsic				0.117			1.96	
Lord Lindsay, Dun Echt.	Repsold		4					Heliometer.
Carrington, Red Hill	Simms	4.5			4.3			

and many others.

THE JOURNEYINGS AND DISPERSAL OF ANIMALS.

IN his recent elaborate work on the "Geographical Distribution of Animals," Mr. Alfred Russel Wallace gives much attention to the subject of migrations as among the means of dispersion, and from his copious treatment of the subject, and various other sources, we glean the following brief particulars upon this subject:

Winged *insects* are perhaps, of all, most admirably adapted for the special conditions found in one locality, and the barriers against their permanent displacement are numerous. Thus many insects require for their subsistence succulent vegetable food during the entire year, which, of course, confines them to tropical regions; some are dependent on mountain-vegetation; some subsist on water-plants; and yet others, as the *Lepidoptera*, in the larva state, are limited to a single species of plant. Insects have enemies in every stage of their existence; foes are at hand ready to destroy not only the perfect form, but the pupa, the larva, and the egg; and any one of these enemies may prove so formidable, in a country otherwise well adapted to them, as to render their survival impossible. But, on the other hand, most varied means of dispersal carry insects from their natural habitats to distant regions. They are often met far from land, carried thence by storm or hurricane. Hawk-moths are sometimes captured hundreds of miles from shore, having taken passage on ships which neared tropical countries, and Mr. Darwin narrates that he caught in the open sea, seventeen miles from the coast of South America, beetles, some aquatic and some terrestrial, belonging to seven genera, and they seemed uninjured by the salt-water. Insects, in their undeveloped states, make their abodes in solid timber, which, transported by winds and waves, may carry its undeveloped, winged freight great distances. Tropical insects are not unfrequently captured in the London docks, where they have been carried in furniture or foreign timber. Insects are very tenacious of life, and nearly all can exist for a long time without food. Some beetles bear immersion in strong spirit for hours, and are not destroyed by water almost at the boiling-point. These facts enable us to understand how not only by means of its delicate wings, but by winds, waves, volcanic dust, and a thousand other agencies, insects may be carried to remote regions.

Mollusca, which are less highly organized than insects, have, of course, limited appliances for journeying, and their dispersal and distribution may involve long periods of time. Fresh-water mollusks are very widely distributed, and this is accounted for by Mr. Darwin by the fact that ponds and marshes are frequented by wading and swimming birds. These carry away with them the seeds of plants and the eggs of mollusks. True land-shells are exceedingly sensitive to salt-water, and yet they are found all over the globe. Experiments on their power to resist sea-water show that a membranous diaphragm, which they sometimes form over the mouth of the shell, enables them to survive many days' immersion in it. They may lie dormant for a long time, some having lived between two and three years shut up in boxes; and one snail, from the Egyptian Desert, was found to be alive after having been glued for four years to a tablet in the British Museum. These facts render it quite possible that they may cross the

sea in the chinks of drift-wood, and this is probably the means of their dispersal.

The inhabitants of the sea seem to have unlimited facilities for journeying, but when we remember that cold water is essential to many fishes, tropical warmth to others, and the deep sea an effectual barrier to a large number of species, it is apparent that the Atlantic may be as impassable a gulf to fishes as to land-animals. Distinct river systems are sometimes inhabited by the same species of fresh-water fish, which indicates that they have some means of dispersal over land. This may be accomplished by changes of level giving rise to altered river-courses and new water-basins, to transportation of the eggs by ducks, geese, aquatic birds, and even water-beetles, and to the agency of whirlwinds and hurricanes, which carry up considerable quantities of water, and with it small fishes.

Reptiles have very limited means of dispersal. Snakes are dependent on climate, being comparatively scarce in temperate and cold regions. They entirely cease in 62° north latitude, and are not found above 6,000 feet on the Alps. They swim rivers easily, but, since they are rarely met on oceanic islands, it is inferred that they have no means of crossing the sea. Lizards are also tropical animals, though they are found higher on the mountains and farther north than are snakes. They possess some means of crossing oceans, and frequently inhabit islands where there are neither snakes nor mammalia. The amphibia extend farther north than true reptiles, frogs being found, sometimes, beyond the arctic circle. Salt-water is fatal to them, and they are probably effectually limited by deserts and oceans.

It would seem, at first, that birds are limited by no barriers, and that a study of their habits could scarcely throw any light upon the causes of animal distribution; but remarkable contrasts in the extent of their range are presented by different groups of birds. Thus, the gulls (*Laridæ*) and petrels (*Procellaridæ*) are great wanderers, a few being found, with scarcely any variation, over almost the entire globe; other species being restricted to one of the great oceans; while parrots, pigeons, and many small perching birds, are confined to islands of limited extent, or to single valleys or mountains. Some birds, such as the apteryx, ostrich, and cassowary, have no power of flight, and, of course, limited means of dispersal. The short-winged birds, such as wrens and toucans, are able to fly but a short distance, and only species endowed with great powers of flight can cross extended widths of sea. Violent gales sometimes carry small birds accidentally to foreign countries, as is shown by the large numbers of North American stragglers which reach the Bermudas. Inadequate supply of food, afforded by the vegetation of a country, oceans, and even large rivers, may serve as effectual barriers to the dispersal of birds. The presence of enemies, of either the young, the eggs, or the parent-birds, may limit the range of a species. In the Malay Archipelago pigeons are

said to "abound most where monkeys do not occur, and in South America the same birds are comparatively scarce, in the forest-plains, where monkeys are very abundant, while they are plentiful on the open plains and *campos*, and on the mountain plateaux, where these nest-hunting quadrupeds are rarely found." When we consider that the pigeon is the most careless and awkward of birds in the construction of its nest, it is not difficult to understand how formidable an enemy it must have in the artful and wary monkey.

The term migration is strictly applied to the annual movements of birds and fishes, which take place in large bodies, and are immediately connected with the process of reproduction. In all temperate regions a large number of birds reside temporarily. Some arrive in spring, and leave in autumn; others arrive in autumn, remain during the winter, but depart in spring; and yet others, birds of passage, pass through the country twice a year, without long delay. The species which winter here are those which build their nests and rear their young farther north, and in returning, on the appearance of spring, they simply act as do those whose homes are nearer the equator. The birds of passage, like our winter-birds, have their breeding-quarters nearer the poles, but, like our summer-birds, seek a warmer climate for the winter. The arrival of migratory birds from warmer regions seldom varies more than a week or two, though their departure is more dependent on the weather, and consequently less constant.

The migratory birds of Europe seem to have a definite route: they "go southward to the Mediterranean, move along its coasts east or west, and cross over in three places only—either from the south of Spain, in the neighborhood of Gibraltar, from Sicily, over Malta, or to the east by Greece and Cyprus." The passage is mostly accomplished by night, and is undertaken only when there is a steady wind from the east or west, and when there is moonlight. It is an interesting fact that the males often leave before the females, and both parents before their offspring; the latter, however, rarely go so far as do the old ones. On returning they vary their course, some following the old, others adopting a new line of travel. In connection with the routes taken by European birds, it is suggestive and interesting to note that fossil remains of huge animals, and the shallow waters in this part of the Mediterranean, indicate that Gibraltar, Sicily, and Malta, must have been at no very distant date united with Africa; the submersion of this land involved considerable time, and the change could hardly have been perceptible from one year to another. It is natural to conclude that the migration, which was at first a land-passage, would be kept up over marshes, then over a channel, and finally over the sea. The sea-passage is a dangerous one for birds, and, from the immense flocks of quails which annually undertake it, large numbers are drowned when the weather proves unfavorable for the passage.

The migratory movement of the North American birds is almost wholly limited to the Atlantic coast, a smaller number being permanent residents than on the Pacific coast, or in corresponding European localities. In Massachusetts the regular number of summer visitors is 106, while there are only 30 species which remain all the year. The number of permanent residents increases as we go southward, but during the breeding-season in any single locality it increases as we go northward until we reach Canada, where more species rear their young than in the Southern States. The extent of the migration of certain birds has greatly altered within a limited period of observation. A Mexican swallow (*Hirundo lunifrons*) first appeared in Ohio in 1815; its yearly range increased, until in 1845 it had reached Maine and Canada, and now its annual migrations extend to Hudson's Bay. The rice-bird, or "bobolink," enters the Southern States in April, passes northward until in June it reaches Canada, and stops in its westerly course at the Saskatchewan River, in 54° north latitude, having widened its range continually as wheat and rice were cultivated over more extensive areas.

A nocturnal concourse of birds sometimes occurs in the neighborhood of large towns near the end of summer, in still, cloudy weather. The notes of well-known birds may be recognized by the skillful ornithologist, at one time faint in the distance, at another near by, while occasionally the stroke of a wing gives a sense of nearness to these remarkable visitors. It is supposed that these noises proceed from migratory birds which, having lost their way, are attracted by the light from street-lamps.

It is thus obvious that the migration of birds is no mere arbitrary matter, but is governed by laws susceptible of intelligent interpretation. Want of food is the most evident cause of their journeyings. As it becomes scarce near the end of summer in the extreme northern limits, those individuals which feel the pressure of want seek it elsewhere, and, in doing so, they press upon the haunts of other birds, until the movement which began in the north has extended to the southern limit. The power of flight in birds makes it possible for them to cross a moderate breadth of sea and unlimited extent of country, and, traveling as they do, mostly at night and high in the air, their movements seem mysterious, simply because they are difficult to observe. But, let us map their comings and goings faithfully as we may, there yet remains the unanswered question, How do these little visitants find their way so unerringly from one place to another, over great distances and apparently unexplored routes?

Some of the largest *Mammalia* are not stopped by any physical obstacle in their journeys over whole continents. The rhinoceros, the lion, and the tiger, have great powers of dispersal, and their possible range is unlimited wherever there are land and sufficient food. The elephant climbs to mountain-tops, difficult of ascent for man, crosses

rivers, and finds its way through the densest jungles. Other groups are much more limited in their wanderings, as witness the monkeys, lemurs, and apes, animals so strictly adapted to an arboreal life that they cannot roam far beyond forest limits. Equally essential to the existence of others is the desert or open country. The range of many mammals appears to be limited by climate, or by its resulting vegetation. Thus the *Quadrumana* are chiefly found within an equatorial belt of 80° wide, but these animals live almost exclusively on fruit, which is the abundant product of the tropics. The polar bear and walrus, which, in a natural state, are limited by the frozen ocean, in confinement may live in temperate regions; the tiger, once regarded as a purely tropical animal, now has his permanent home in Mantchooria, a country of almost arctic climate; and, in post-Tertiary times, the elephant and rhinoceros roamed over the northern continents, even to regions beyond the arctic circle. Hence it does not follow that animals, which we now see inhabiting extremely warm or extremely cold climates, may not, under changed conditions, thrive equally well elsewhere.

Valleys and rivers often prove effectual barriers to mammals. Thus, in the plains along the Amazon, many species of insects, birds, and monkeys, are found extending to the river-bank on one side, which do not cross to the other. And on the northern bank of the Rio Negro there are found two monkeys, the *Brachiurus couxion* and the *Jacchus bicolor*, which are never seen on its southern bank. Many mammals can swim well for short distances, but none over any great extent of sea. It is not unusual for the bear and bison to swim across the Mississippi, and from Lyell's "Principles of Geology" we learn that in 1829, during the floods in Scotland, pigs six months old, which were carried to sea, swam five miles back to shore; and it seems entirely probable that wild-pigs, from their greater activity and power of endurance, might cross arms of the sea twenty or thirty miles wide, and facts in the distribution of these animals lead us to infer that they have sometimes done so. Lemmings, rats, and squirrels, often migrate in enormous bands, but they generally perish in the sea-water. And, admitting that many mammals have power to swim considerable distances, it remains true that a channel ten or twenty miles wide would, in most cases, prove an effectual barrier to them. The bats, provided as they are with wings, and the *Cetacea*, which swim, have exceptional powers of dispersal. In the arctic regions glaciers give rise to icebergs; these descend to the sea, often carrying with them masses of earth and some vegetation. Such arctic quadrupeds as frequent the ice, as well as occasionally true land-animals, might often be carried from place to place in this way. But the uprooted trees and rafts of drift-wood which float down large rivers and out to sea, are more effectual agents in the dispersal of animals. Such islands or rafts are sometimes seen drifting hundreds of miles from

the mouth of the Ganges, bearing upon their surfaces erect, living trees. And the Amazon, Orinoco, and in fact most large rivers, present at times similar spectacles. Here, then, is most ample opportunity for carrying all small arboreal animals out to sea, and, although they are liable to perish, unusual tidal currents may bear them great distances safely from their native country.

THE EARLY MAN OF NORTH AMERICA.[1]

By A. R. GROTE,

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A CHILD is not fully formed in body or developed in mind when it is born. It behaves at first without experience. That is the reason we do not always understand baby when it "acts so." Our own behavior is the result of our experience. Baby moves its hands and twists its legs without knowing why. But it gradually selects from among these movements those which are found to satisfy its wants, and in the future performs such actions only. It uses its voice in the same way, as shown by Taine and other writers, gradually picking up such words as it finds are answered. Again it acquires, always by experience, the idea of distance. The moon seems so near that the child wants it taken down to play with; while the position of objects close at hand is equally misjudged. And so with the senses of hearing, smelling, tasting, and feeling.

It does not know at first where the pin is that pricks it; and, even if we slap it on the very part recommended by Dr. John Brown for the purpose, baby will not be able to locate the injuries, though it may have a general sense of discomfort, and resent the injustice in its feeble little way. Just as it passes through a process of self-education by experience, its mind receives constant correction as to the nature of surrounding objects. Baby's principal opinion at one time is, that inanimate things possess like feelings and properties with itself. This idea of baby's we sympathize with when we pick up a chair over which it has stumbled in its efforts to walk, and pretend to whip "that naughty chair," until baby stops its crying and is propitiated by the supposititious sufferings of the chair. This personification of objects is less and less obtruded as the baby grows and becomes better acquainted with the nature of its surroundings. But it is hardly ever entirely dropped, even in after-life, when it becomes in us transferred to matters beyond the reach of our knowledge. These observations on our children become important when we study the actions of races of men less cultured than our own. We find such

[1] A lecture delivered under the auspices of the Buffalo Society of Natural Sciences.

races using their hands to less advantage, as well as other bodily organs, the seats of the senses.

Savages exercise their minds less, and personify more than we do. Like children, they say more readily *no* than *yes* to all questions affecting their bodily advantage. They are afraid of change. All children and all savages are conservative. The savage has not passed the mental state of our own children. It is impossible for a child to conceive of any change in the world outside until it has had some experience of such changes and has reflected upon them. Even then it is hard for the child to understand the appearance of this city of Buffalo, for instance, ten years before the time when its mind first received permanent impressions. It is from this fact that youth appears so long when we look back upon it, as well as from the fact that our early impressions made upon the "clean slate" of the brain are more enduring, underlying and peering through our subsequent experiences. Even to ourselves, sensible to the hope of change, and therefore of a bettered condition of things, it is difficult and even distasteful to turn to the record of the past and make it give up its dead. It is hard for us to make a mental picture of the site of this city when Red Jacket lived hereabouts; scarcely possible, when, farther back still, in 1687, La Hontan traversed this place. But in the history of North America we can go back by the light of creditable documents to the year 986, when Biarne, the son of Bardson, set sail from Iceland, and, losing his way, came in sight of Newfoundland. Back of the earliest discovery by our race of this continent of North America must lie the history of the Indian. In Mexico traditional historic accounts take us back as far as the sixth century. And, for a still earlier time and its events, we have to penetrate the surface of this continent itself. The earth holds the further answers to these questions. In a story of ancient Greece, we read that there was a dispute as to whether Salamis had formerly belonged to the Athenians or the Megarians. When it was referred to Solon, he caused the graves to be opened. It was found then that their occupants were buried according to the custom of the Athenians, and not of the Megarians. The dead men settled that question. The testimony of the dead Athenians dispensed with the formula of an oath, and was yet accepted. No appeal was necessary after such evidence, just as no statute of limitation could bar a trial of such importance. It was a case of supplementary proceedings that commanded respect.

The earth of this continent shows us that before the Indians there has been a people whom we call Mound-builders—that is, mounds were thrown up here by men whose bones we find in them, lying among rough tools and utensils, and after the mounds we name the race, who, perhaps, were not a different people from the Indians.

But for these mounds we would not know of the men who built them. They are mentioned in no history, human or divine. What

was there before the Mound-builder? I would speak to-night of what must have been long before *his* time—of *early*, though perhaps not *earliest*, man in North America. We must know this early man by our experience of his traces. New observations of fact and the ideas they have awakened in myself are put forward, so that you may judge of the reasonableness of the conclusions. And here any boy will afford a competent illustration of the evidence. Almost the first thing that our boys do is to throw stones. It is one of their ways of saying No. There is more than one parallel between savages and our boys to be maintained. Just as the state of mind of the adult savage is paralleled by that of our children, so we must expect that so common a weapon as a stone is to our boys must be extensively used by savages. And this, in fact, is what we do find. There was also a time when this stone-throwing was the occupation of grown men of our own race. Stones were used in the warfare of the Celt and the Roman. We remember that David, a Semite, used a pebble from the brook. And we shall find that men of other races, and before David, resorted to the same weapon for all the purposes which in David's time, and with his race, were partly served by metals. There is, then, not only a parallel to be drawn between our boys and savages in certain ways, but there exists one between these boys of the present and our own men of the past. Just as, when cutting into the crust of the earth, we find the remains of animals and plants which once inhabited its former surfaces, the simpler forms below, the more complex above, so we find the remains of man's tools and implements in the clays and gravels of the last geological period of the globe, and with a like sequence in their character. The oldest and lowest forms of tools are simplest; the newer and nearer to the present surface, the more varied and complex. We have seen that the simplest weapon man could use would be a stone. Even now a wagoner with broken cart looks around naturally for a stone to pound with, and so mend his ways. He picks up a stone on occasion as his ancestors did on most occasions. For the moment he is in the Stone age. And he uses what the earliest man must have undoubtedly used, a stone just as it is. There must have been a time when men picked up such stones as came in their way at the moment with which to throw at animals, to break their food, to injure their fellow-men. Such stones, unaltered by use, can no longer be identified.

It is easy to see how, through long lapses of time, men continued to select stones, with an ever-increasing care as to their shape and size. The best to fling, the surest to hit, the sharpest to cut, were picked out, assorted in leisure moments, stored for future use. The hunter, meeting with game, could find no stone suited to bring it down at the moment, and so came at last to carry this primitive shot about with him in his hunting. The way from such a process, and a mode of improving the best of these stones by an artificial changing

of their shape and size, were clearly pointed out by experience. And there must have been a gain in the process to such an inventive tribe. No more were long searches for properly-sized stones necessary. By means of harder stones others were chipped and shaped, and so much time was gained from looking for stones and devoted to obtaining food. And tribes using artificially-shaped stones must have had a superiority over those who relied on what natural stones they found at the moment. They stood in less danger of starvation. In the absence of other remains, the presence of roughly-fashioned stones will be the earliest reliable trace we shall find of the existence of men. In Europe such stones have been found and described by several observers. In North America we owe their discovery to the zeal of Dr. C. C. Abbott, aided in funds for excavation by the Peabody Museum of Archæology, of Cambridge, Massachusetts. The rough-stone implements discovered by Dr. Abbott in New Jersey are chipped so as to form an irregular cutting edge. They are flattened on the under side and broken to an edge from the upper. The material itself is basalt, a common kind of mixed rock of compact texture. As we find them, the surface is slightly rusted, from the particles of iron in the stone. This kind of rock is common, and the tunnel of the Erie Railway at Jersey City is cut through stone of this kind. North American rough-stone implements vary little in size and pattern, although, when we examine all the kindred rough-stone implements of the world yet known, we see that, as a class, they become gradually more determinate in their shape and the chipping more regular; they come more into the shape of spear-heads, and, perhaps, large arrow-points. Above the rough-stone implements we find those of polished stone; a departure showing that man was no longer satisfied with his first rude fashioning of his implements. Then we find the metals; and of these copper, being more pliable, is first beaten cold and worked into shape for use. Then the process of smelting and mixing with harder metals, such as iron, came to be employed; and to-day we are doing just what man has always done, improving our tools so that we may better our condition.

Surveying the whole field gone over by scientific men in recent times, we must say that these different ages have merged gradually into one another. The age of rough-stone implements or paleolithic, the age of polished-stone implements, or neolithic, the ages of copper, bronze, and iron, have succeeded each other without the possibility of our drawing the dividing line, any more than we can say exactly when what we call the middle ages ceased and modern time came in.

Certain implements are, indeed, rough stone, and others polished, but between them are intermediate specimens, and both kinds seem to have been sometimes in use at the same moment with the same people. Again, the introduction of bits of copper in some of the earlier graves precedes the fashioning of copper axes. It is a similar

question to that as to species. It is not necessarily each time a different people, but sometimes the same, at first using a more simple and then a more complex implement. All mankind have not progressed equally. Some are in the Stone age now. There have been arrests in development, and a comparison of the points which the different races have reached will show the differences in standing between them. In Europe, Lyell has given a very complete account of the different kinds of implements found in one locality, the valley of the Somme. In the peat-bogs on either side of the river are found Roman weapons, belonging to the age of metals. In the gravel and clay-beds below, polished and rough stone implements are found. In North America the iron tools are wanting. The Indian was in the Stone age at the advent of Europeans. The Mound-builders had used copper, but the process of smelting and the use of iron had not been reached by them.[1]

QUATERNARY.

AGE OF MAN.

Autocene.	Holocene.	Pleistocene.	Ice-Period.
Alluvium.	Peat-beds.	Gravel-beds.	Unstratified drift.
Age of Metals.	Neolithic implements.	Paleolithic implements.	Paleolithic implements.
	Mastodon.	Horse.	Reindeer.

TERTIARY.

AGE OF MAMMALS.

Pliocene.	Miocene.	Eocene.
Horse.	Miohippus.	Orohippus.
Pliohippus.	Mesohippus.	Eohippus.
Protohippus.	Brontotherium.	Coryphodon.
		Tillotherium.
		Dinoceras.

In the accompanying diagram, while I have indicated the geological succession of the implements of man, you must bear in mind that, since stone implements are yet used in some parts of the world, they are there found in surface or alluvial deposits. But for our race the Stone age has passed, and, to find in Europe the implements our forefathers used, we must go in most cases into lower than surface-beds. And Dr. Abbott has drawn attention to the fact that there is a great similarity between the North American and European rough-stone implements. This does not indicate so much identity of

[1] The difficulty of supposing man to have been originally introduced into North America during the Quaternary lies in the fact that he was most probably in the Paleolithic age when the migration was made. This difficulty vanishes, if, as I suppose, man entered upon possession of this continent during the Pliocene, before the Ice period had interfered with a passage from the north by land. This will leave us free to consider the American civilizations indigenous.

race as identity of culture, while there is great probability that both are implied. We must remember that as we go back in time we should find the races of men less numerous than at present—the nearer we get to the common stock from which it is believed all mankind must have sprung. The survival of stone implements is not unlike the persistence of older forms of life. The gar-pike (*Lepidosteus bison*) still inhabits our lakes, but the age when the ganoid type of fishes prevailed has long gone by. In order to make the age of the North American rough-stone implements clear, we must study the geological evidence.

Clay and gravel are made, we know, from the primitive rocks. The atmosphere and the rain loosen large pieces of rock from the mountains, and they are broken in the beds of streams by the action of the water. The fine particles are produced by the rubbing of the stones together; the water grinds the broken rocks down smooth, and makes pebbles of them. Gravel, sand, and clay, produced in this manner, become sorted out by the action of the water, or *stratified*. From a study of the action of existing glaciers or ice-masses on the Alps, or in the North, it is seen that clay and gravel are also made from the primitive rock, ground out by the slow movement of the ice. The mass of dirt and stones is discharged at the edge of the glacier much as a bar is formed by a river.

But there is this difference, that the bar made by the glacier, and which we call a moraine, contains its gravel and clay and bowlders, in a confused mass, with little sorting, and thus *unstratified*. Now, these rough-stone implements have been found in New Jersey by Dr. Abbott, in unstratified beds of material, which are evidently, from their composition, ancient moraines. There are, we know, different degrees of evidence. A fact may be either demonstrated, or shown to be probable, or possible. I leave it to you to judge whether these circumstances do not demonstrate that North American rough-stone implements are as old as the beds in which they are found. To me, it seems clear that the men who used these rough tools dwelt on the edge of the glacier, and their implements have become buried in the moraines which were forming at many different points during the ice-period. Nor can we refuse to admit what this demonstrated fact implies, the great age of man in North America. I have taken, on a former occasion, the sum of 100,000 years as the time that has probably elapsed since the retiring of the glacier from the valleys of the White Mountains, in New Hampshire. This figure was arrived at after a calculation based on the ratio of movement of bodies of ice, and the round number may be considered as an under rather than over estimate. But, at whatever time during the glacial epoch the moraine was formed, in which Dr. Abbott found these implements of early man, it is quite clear that this knowledge alone will not give us the duration of man's existence in North America; for it is certain

that man could not have originated at the foot of the glacier. The ice must have met him toward the close of the Tertiary period in the northern parts of Asia and America, and forced him southward; or, at a later time, it must have found him on the main belt of this continent. The Tertiary origin of man is presupposed, from the fact that he had submitted to a race-modification fitting him to endure the cold.

Let us consider for a moment what this glacial epoch really was. As to its occurrence, the ice has left its mark on the rocks, and we see its moraines and transported bowlders over a vast portion of this continent from Virginia to the Pacific. There is no doubt that a vast ice-sheet, a continental system of glaciers, was here at a distant time. It has transported masses of rock, and left them on the summit of Mount Washington, where they still remain, and to do this it must at one time have overtopped the mountain. The ice gradually spread from the north, and its progress was slow, as we judge of time—so slow that it must have seemed immovable and unchanging from year to year, to the man of the epoch, just as it seems to us now; and just as slowly as it advanced it retired again to where it is to-day.

The glacial epoch comes in between the present or Quaternary division of time and the Tertiary. In order to estimate its effects, we must briefly consider the aspect of the earth before its advent and in the preceding epochs.

There are two principal conclusions to be drawn from an examination of the fossil remains of plants and animals during the Tertiary. The first is, that the climate over the largest portion of the globe was then equable. There were then apparently no seasons—the summer seems to have been perpetual. The proof of this lies in the fact that there was a general distribution of plants and animals over the whole surface. In Greenland and Arctic America there were forests of trees, as attested by the remains of their trunks, stumps, and leaves. The same regions reveal to us coal-fields, and the fossil remains of reptiles like those we find in beds of the now temperate zone. We find beds of coal on desolate islands in the Southern Pacific Ocean, islands so cold and barren as to afford now but weak and little plants; whereas these beds of coal attest the presence once of a luxurious vegetation, of which they are the remains.

The second conclusion is, that the Tertiary was the richest in the number and kinds of the higher animals as compared with the present or any preceding geological period in the earth's history. Then our Territories supported all the various kinds of animals, for instance, which culminated in the horse. The remains of hundreds of species of animals have been collected by Prof. Marsh from a region which now supports but very few.

Prof. Huxley has, by his now famous lectures in New York City the past year, made popularly known the discoveries of fossils by

Prof. Marsh in the Western cretaceous and tertiary beds. It remains but to add a link to the genealogy of the horse, discovered by Prof. Marsh since the time when Prof. Huxley lectured. You will remember that Prof. Huxley showed that there was a regular series of progressive forms from the Eocene *Orohippus* to the recent horse, in the character of the teeth, and in the structure of the fore and hind feet. There was more than that, perhaps, when we consider that there was an increase in size, in length of limb, and consequent activity, of the animal. In the *Orohippus* we have four toes on the front and three on the hind limbs, and so far Prof. Huxley was able to trace the genealogy of the horse with its single toe down toward the type of mammals with five toes. But we can now go a little further in the process of the evolution of the horse. In New Mexico, in a fossil bed, the horizon of which is below that in which the *Orohippus* occurs, Prof. Marsh has found the remains of an animal which he calls the *Eohippus*. The feet, which are very much like those of the *Orohippus* with their well-developed four toes in front and three behind, show a rudiment of the outer or fifth toe. The *Eohippus* was an animal as large only as a fox, though perhaps a little stouter, and, from the structure of its limbs, is the nearest yet discovered progenitor of the horse to the usual five-toed mammalian type. And in his lecture Prof. Huxley anticipated the actual discovery of the *Eohippus* by showing that such a form must have existed as the progenitor of the four-toed horse. Animals, also, which were the prototypes of the camel, have been there discovered by Prof. Cope. Strange if, at the time when the whole earth presented such a profusion of vertebrate life, man should not also have appeared upon the scene! The conditions were never so perfect, either before or since. Over this field of luxuriant life, the cold broke in. The ice commenced to form, and then to move in masses, scattering or extirpating the plants and animals. There were migration and adaptations. Such animals and plants as could adapt themselves to the cold persisted. To probably smooth-skinned elephantoid types, the woolly mammoth succeeded in the northern regions. Stunted willows replaced tree-like plants of the same botanical family. If it met man, it must equally have modified his habits of life and his physical characteristics. It must have made something like an Esquimaux of him. As to the cause of the glacial epoch itself, from a study of all that has as yet been said on the subject, we must ascribe it to upheavals of land in the north, and a change, perhaps a consequent change, in the earth's position toward the sun. There was, it seems, an elevation of the earth's crust and a variation in the earth's axis; which latter, in order to have produced the climatic effects of former geological periods, must apparently have been more nearly perpendicular than it now is. It is probable that oscillations then set in, which may make a second glacial epoch probable, although of this we cannot speak with certainty. Evidence is

already at hand, collected by European observers, that the glacial epoch itself was not continuous, but intermitted by a warmer time during which the ice retreated to reoccupy that portion of its former territory from which it has now finally retired. Prof. Dana has contributed some evidence of a similar action on North American territory. But for our present purpose a general view of the Ice period is all that we need. Evidence is at hand that the glacier, at the time it traversed our territory, was accompanied by plants and animals different from those now inhabiting the Atlantic States.

Remains of the reindeer have been discovered by Prof. Dana in clay-beds thrown together by the action of ice. This animal is now, as we know, confined to arctic regions, but then ranged the valley of the Connecticut. And there has been a sort of natural trap set for the animals and plants of that time, which caged a part of them, so that we may examine some of their live descendants.

It has been found that the condition of the tops of high mountains, such as Mount Washington in New Hampshire, and that of high northern regions, are very similar. It is calculated that a change of one degree Fahrenheit takes place in the temperature for every three hundred feet of vertical height. On a level the same change occurs for every sixty miles as we journey northward. We should have to travel, for instance, from Boston to Hudson's Bay, as Agassiz has shown, before passing over the same range of climatic changes as we do in one day in the Alps, thus causing a narrow strip of Alpine flora to correspond to a broad zone of northern vegetation. The mountains are thus compressed models of the physical conditions of the latitudes of the surface.

In the tropics we have mountains crowned with ice, whose summits reproduce the condition of the north-pole; and, as we descend their sides, we pass through belts of climate ever increasing in warmth, to the plain beneath, where we meet with the condition of the torrid zone. Now, during the glacial epoch, when the surface of our Middle States was covered with a coat of ice, the plants and animals had been swept southward of the White Mountains. They bloomed and lived in the spring-tides that softened the edge of the glacier, and enjoyed the short summer that there ensued at the source of streams fed from the melting ice. But, when the glacier retired, the summers over this region becoming longer, and the winters shorter, plants and animals followed the ice and their congenial climate northward to the valleys of New Hampshire. Out of these valleys the glacier finally departed also, but not without leaving some of its retinue behind. After the main glacier had left the valley, Mount Washington and Mount Adams still remained largely covered with ice, and a system of *local glaciers* filled the clefts and gorges of the hills. Allured by these, some of the plants and insects were retained and did not follow the bulk of their companions who were on their long march to the

north. But year after year it got warmer, and the local glaciers shortened, extending less and less into the valleys. The trapped insects could not then rejoin their mates, but instead climbed the mountain, dwelling farther and farther up as time progressed and the climate changed. At length they reached the summit of Mount Washington, where we still find some of them, and whence there is no escape. The plants formed patches in congenial spots on the sides of the mountain, driven upward by the new flora filling the valley from the southward. Now, in examining these colonists, we find among them the herb-like willow (*Salix herbacea*), its short stems hardly rising above an inch from the ground, and other species of plants which we have to go far north to meet again. There, too, the White Mountain butterfly (*Œneis semidea*) appears year by year, swaying in feeble flight over its narrow range, while its congeners are found one thousand miles to the northward in Labrador. These examples could be easily multiplied.

But this sort of mountain-trap was not large enough to hold such game as men and reindeer. These both went northward, and are not to be found alive with us; but the one left his implements, and the other its bones, to tell of their presence at that time, and in these latitudes.

When we come to the question as to the descendants of this early North American man, we cannot avoid studying for a moment the movements or migrations of man over the surface of the earth generally. I think we may divide his migrations into two main classes from their motives:

A *primitive* migration—one influenced solely by physical causes affecting his existence, and which must have been in more extended operation in early times when he was unprovided with means of his own invention against a change in his surroundings. Such migrations are operative now among certain of our Indians, who move from place to place with the game upon which they subsist and with the season.

A *culture* migration—one arising from a certain stage of intellectual advancement when the movements of man are determined by ultimate and not immediate considerations. The movements of the Indo-European races fall within this category. Besides these, there are to be distinguished *accidental* migrations, which man submitted to against his will. We know that insects and plants are so transported. Birds and ocean-currents carry seeds from land to land. Insects on a blade of grass or a fallen bough are carried down a river by the current to found colonies of their race far from their place of origin. And such circumstances give rise to races and varieties among species modifiable by the peculiarities of their new localities. The accidental migrations of man may be considered as belonging to the epoch of culture-migration, since they must more usually have oc-

curred with a race advanced in the art of navigation. A separation of communities under the pressure of storms, earthquakes, volcanic eruptions, may have naturally happened, however, in the earliest times. Neither the man of *primitive* nor of *culture* epochs is exempt from the control of the elements on all occasions. We must agree that we may account in great part, and reasonably, for the variation of man by the difference in his present physical surroundings.

The essential unity of origin of all the races of mankind is believed by the great majority of scientific men.

The study of the migration of mankind shows us that there has been replacement everywhere; that people now inhabiting any known country have not always inhabited the same tract of land. At the same time suppose our race to vanish entirely from this continent, leaving only ruined cities and implements behind, how difficult would it be to get a true history of our migration hither! Suppose again we had no certain account of how our forefathers crossed the Atlantic, how diverse would be our traditions! Europeans have no authentic account of how they came to be in Europe. A great deal of our American dogmatism and Philistinism is to be ascribed to the fact that we know our origin. We came from England or Germany, and that answers such questions sufficiently. It is as far as we usually think. But now we see that we cannot speak of autocthones, or people sprung from the soil they now cultivate. Such a boast has been made by more than one race, indeed by people of such different culture as the ancient Athenians and the modern Esquimaux. So that we may not conclude too rashly that the people who have left only traces in any country are extinct, because they have been replaced by a different population, just as we have replaced in the eastern portion of North America the Indians. Their descendants may exist elsewhere. This seems to be the case in the present instance, and just as the same kinds of reindeer, butterflies, and plants, of the time when the ice covered these States, no longer live here, but in a far north, so the man of the glacial epoch of the present United States has in all probability wandered after the ice—a primitive and unconscious migration determined by the shifting of his congenial physical surroundings. And the Esquimaux, as of old skirting the glaciers, the only inhabitants of the shores of Arctic America, and extending in scattered companies for nearly five hundred miles on the coast of Asia beyond Behring's Straits, may well be the modern representatives in a direct line of descent of early man in North America. They were found inhabiting this territory by Europeans first in 1616; and since that time they have been found as far north as we have been able to penetrate. The limit of their range to the southward seems to be about the fiftieth degree of north latitude on the eastern, the sixtieth on the western side of America and the shores of Hudson's Bay.

Our knowledge of the Esquimaux is far from complete. They call themselves *Innuit*, not *Esquimaux*, and the name signifies *the people*. Although divided into tribes and smaller companies, they are very uniform in their physical appearance and customs. A tribe met with by Sir John Ross about 77° north latitude believed themselves to be not only the only Esquimaux, but the only *people* in the world. As their numbers are comparatively small, and they have a total range of about 5,000 miles of coast-line, it is evident how a tribe might exist for centuries without meeting any competitors for seal and bear meat in its range. The different tribes practise a sort of communism with regard to their possessions. Different families dwell together in one house, and rely upon each other for mutual support. So much, in brief, we may say here of this people. With regard to their affinities, they are from their speech a branch of the Turanian family, and allied to the Hungarian, Turkish, Lapp, and Basque races. As to their habits, while their morals seem to be good, they are most voracious eaters, from the fact that they cannot always depend on their supply of food, and so gorge themselves when they get a quantity. Parry tells of an Esquimaux boy who ate eight and a half pounds of seal-meat, one and a half pound of bread, one and a half pint of soup, and drank three wineglasses of gin, a tumbler of hot whiskey-and-water, and five pints of water, consuming the whole, between intervals of rest, in one day. They seldom wash except in summer, in which I think they are excusable to some degree, in the absence of proper heating apparatus in their huts.

As usual, travelers and scientists speak badly of boys. It is always the *boys* who are doing the worst actions, be they Esquimaux or New-Englanders. While I myself, in the present lecture, am guilty of this unavoidable presentation of the facts, I yet believe that the most of the wrongs of this world are committed by grown-up persons, and I look to the growing generation of boys to make better and wiser men than their fathers. They have the benefit of a greater amount of experimental information stored up for them in books from which they can take fresh departures in knowledge and happiness.

It has been my aim in the present lecture to give you the result of latest information on the earlier man of North America, and at the same time to indicate some of the different branches of science which it is necessary for us to pursue in order to understand anthropology or the study of man. We have called upon geology to describe the strata in which we find the relics of man, and to explain their probable age and the manner of their deposition. Archæology has shown the progress from the simple to the complex in the various implements used by man, and has classified them. Ethnology has allowed us to discriminate between the different races of mankind, to study their habits and migrations, and classify their religious. Biology has enabled us

to study the different stages through which man as an individual passes from infancy to maturity. Psychology, finally, has taken cognizance of the various facts supplied by the other sciences, and has led us to understand how, man being known, and his environment being comprehended, we are to interpret their interaction.

There are two conclusions which I think we are warranted in drawing from the facts here presented. The first refers to the actual relation between time and development. Just as geology teaches us that the simpler organisms have existed on the earth through vastly longer periods than the more complex, so it shows us that the ages during which man used simpler and stone implements were greater in duration than those in which he has used more complex and metal tools. Let us compare what we are doing now with metals, and what we did with them during the miserable epoch we call the "age of chivalry," of which sentimentalism still gives us false and fanciful pictures. The second conclusion springs from the first. As the true history of our own race shows that we came from a low and brutal state, common once to all mankind, so the facts of our present condition give us reasonable hope for a better future. Let us, then, stand on the highest points of knowledge in all its departments, for these are touched with light. We must reach these heights by continual reading, observation, and experiment. The result of these is culture. All thought has an added beauty as it approaches the truth, but what is needed is to attain to clear conceptions. Our impressions are blurred because we do not see facts clearly in all their relations, and such impressions are ugly because they are imperfect. We are yet in the morning of culture. We are only becoming sweet as wild-apple trees grafted on single boughs. It is not so much that we are sinners as that we are sluggish and stupid that is the matter with us. It is certain that there is a better time yet to come for our race upon this earth than the present. It will be reached by a continuous exercise of our brain-power, giving us right reason at last, the permanent correction for faults of conduct and for errors in our ideas. Sir Henry Maine has said that "conceit and skepticism are the products of an arrested development of knowledge."

BIOGRAPHICAL SKETCH OF THOMAS EDWARD.

MANY of our readers, as their attention is arrested by the portrait we furnish this month, will glance at the name beneath it, and musingly ask themselves whether they have ever seen or heard it before. They will say, perhaps: "There were several Edwards, who were Kings of England, and there was Edwards, who made a book upon the will; and there is Milne-Edwards, the great naturalist of

the French Academy; but—Thomas Edward—Tom Edward—who is he? and what business has his portrait in THE POPULAR SCIENCE MONTHLY, where we expect to find likenesses of only eminent scientific men?"

Well, the Thomas Edward whom we represent is in his proper place; and, if he has not been heard of before, he ought to have been. He was certainly not a King of England, but he has been a king and a hero in his own way; and we are glad to note that the Queen of England and Empress of India has recently honored herself by honoring him. Nor has Thomas Edward, like the great Jonathan, ever written on the will; but he is one of Nature's illustrations of it, and is himself a living treatise on the force of the will. And, although he is not a rich Anglo-French naturalist, the pet of the Academy, and applauded through Europe, he is nevertheless an eminent naturalist, who in an obscure Scotch town, without education, without means, without books, without encouragement, and without the acquaintance of men of science—a poor, day-laboring mechanic, with a large family—has done original work in science, of a quality and extent that would have carried half a dozen common men into the American Academy of Sciences, or the Royal Society of England. Thomas Edward fought his way alone, inspired and sustained by a love of Nature which with him was nothing less than an ungovernable passion; and, although working in long obscurity and bitter privation, and under difficulties that would have crushed the spirit of ordinary men, he has at length met the reward he so richly deserves, by falling into the hands of a gifted and admiring biographer. Well can he have waited, and much can he have suffered, who secures the genius of Mr. Smiles to write his life while he is yet living, the skillful pencil of Reid to illustrate it, the aristocratic house of Murray to publish it in his native country, and the enterprise of the Harpers to reprint it in the United States. We make free use of Mr. Smiles's work [1] in the following pages.

THOMAS EDWARD was the son of a hand-loom weaver, and was born near Aberdeen, in Scotland, in 1814. From his birth he was difficult to manage. His mother said of him that he was the worst child she had ever nursed. He was never a moment at rest, his feet and legs seemed to be set on springs. In babyhood he showed an impulse to leap from his mother's arms after flies. As soon as he began to walk he made friends with the cats and dogs, and would toddle out into the streets to cultivate the acquaintance of the hens, ducks, and geese, and would watch the pigs in a pen for hours. As he grew older he became a desperate rambler and runaway, and developed a

[1] "Life of a Scotch Naturalist: Thomas Edward, Associate of the Linnæan Society." By Samuel Smiles, author of "Lives of the Engineers," "Self-Help," "Character," "Thrift," etc. Portrait and Illustrations by George Reid, A. R. S. A. Harper & Brothers.

passion for collecting all sorts of natural objects, crabs, worms, beetles, rats, tadpoles, frogs, snails, leeches, mice, birds, and birds'-nests, which he would bring home, and which were the nuisance and pest of the house. His mother protested and forbade, and threw his "venomous beasts" away, but it was of no use. He was threatened with punishment, and the same night brought in a nest of young rats, when, of course, he was flogged. But blows did no more good than words. When sent to carry his father's breakfast, he cut for the seashore. One morning his mother tied him up firmly to a table to prevent his going out, and set his little sister to watch him. As soon as his mother was absent, with a mixture of promises and threats he made his sister help him, when they pushed the table so close to the grate that he was able to burn off the rope and get away. Tom got at liberty and had a good time that day in the fields. One morning his father hid his clothes, so that when the boy got up he had "nothing to wear." His mother tied a bit of old petticoat around his neck, saying, "I'm sure you'll be a prisoner this day." He tied a string around his middle, hid himself awhile in the entry, and at an opportune moment bolted into the street, and was soon at the shore hunting for crabs, horse-leeches, puddocks, and sticklebacks. But the exposure was too much for him, and he had a long fever, with delirium, hanging between death and life for several weeks. When he recovered, the first thing was to inquire after his beasts. When but four years old he was thrashed and starved and shut up to keep him at home, but he was self-willed, determined, stubborn, and thoroughly incorrigible. He wandered about the beach, rambled over the country, learning all the best nesting-places of the birds—in the woods, plantations, hedges, streams, and mill-dams. He was inquisitive and thoughtful, often asking for information, but rarely getting it. He knew how birds made their nests, and how the flowers grew out of the ground, but he did not know how the rocks grew. He asked his parents, and they told him the rocks had existed from the beginning. This did not satisfy him, so he went to the quarrymen. "How do the rocks grow?" asked he. "Fat say ye?" Tom repeated the question. "To the deil wi' ye, ye impudent brat, or I'll toss ye owre the head o' the quarry!" Once he saw a paper-like something up in a tree, with lots of yellowish bees about it. This started his curiosity, and he tried to get the other boys to join him in securing it. They refused and ran home, leaving him alone. He climbed up near the limb where it was suspended, and was met by a sting which he thought was more painful than any he had ever had before. He sucked and blew the wound, but there hung the wasp's nest, and he could not leave it. It was growing dark, he could not put it in his bonnet nor in his stockings, so he stripped off his shirt, and, though getting numerous stings, wrapped it around the nest, detached it, and carried it home. His father, seeing him shirtless, threatened him with

the strap, sent him to bed, and the shirt, with its contents, was soon put in a bowl, and covered with boiling water.

The time at length came when Tom Edward must be educated. To be sure, he had been educating himself pretty rapidly, but he must be sent to school. This he hated. He could not bear the confinement. When between four and five years old he was sent to a dame's school, kept by an old woman called Bell Hill in the garret of an ordinary dwelling-house. But he often played the truant, and would rather be in the fish-market than the school-room. His truancy soon became known to his mother, who then employed her mother, Tom's granny, to take him to school. But Tom rebelled against his granny's supervision, and got away from her so often that she had to drag him "by the scruff o' the neck." Once he slipped away from her, and ran for the water, and was in the act of getting a lot of horse-leeches, when his granny, who had pursued him, caught him by the neck. He let go of the stone, and, making a sudden bound, upset the old woman in the water. His comrades called out, "Tam, Tam, your granny's droonin'!" Tom was off, and did not get home till night, when his mother abused him for a ragamuffin who tried to drown his granny. For once his father was in good-humor, and remarked to his wife that "granny should beware of going so near the edge of such a dirty place." The scapegrace returned to school, but did not learn much. The education that Bell Hill gave was rather theological; she prayed, or, as Tom called it, "groaned," with the children twice a day, and in one of these devotional exercises Tom came to grief. She forbade him to bring his "nasty and dangerous things" to the school, but it made no difference. He had a noisy jackdaw at home, of which he was very fond, and one day he stuffed it inside of his trousers, and took it to school. While Mother Bell was at prayer the daw became restless, got its head out, and began to scream. "The Lord preserv's a'! Fat's this noo?" cried Bell, starting to her feet. "It's Tam Edward again!" shouted the scholars, "wi' a craw stickin' oot o' his breeks!" Bell went up to him, pulled him up by his collar, dragged him to the door, thrust him out, and locked the door after him, and Edward never saw Bell Hill's school again.

Tom was next sent to a school governed by a master who had great faith in what is called the "taws"[1] as a means of education. But the boy's old habits followed him, and one day he smuggled into the school a broken bottle, containing horse-leeches and the grubs of water-flies. Mr. Smiles relates that "all passed on smoothly for about half an hour, when one of the scholars gave a loud scream, and started from his seat. The master's attention was instantly attracted, and he came down from the desk, taws in hand. "What's this?" he cried. "It's a horse-leech crawlin' up my leg!" "A horse-leech?" "Yes, sir; and see," pointing to the corner in which Tom kept his

[1] "Taws," a leather strap, about three feet long, cut into tails at the end.

treasure, "there's a bottle fu' o' them!" "Give me the bottle," said the master; and, looking at the culprit, he said, "You come this way, Master Edward!" Edward followed him quaking. On reaching the desk he stopped, and, holding out the bottle, said, "That's yours, is it not?" "Yes." "Take it, then—that is the way out," pointing to the door; "go as fast as you can, and never come back; and take that, too!" bringing the taws down heavily upon his back. Tom thought that his back was broken, and that he should never get his breath again. Tom's mother took him back to the school-room door, but before she could open her mouth the master abruptly began: "Don't bring that boy here! I'll not take him back—not though you were to give me twenty pounds! Neither I nor my scholars have had a day's peace since he came here."

Tom was now sent to a third school, where he staid eighteen months, but did not learn very much. The Bible was the reading-book, and he got so that he could read it, and also repeat the Shorter Catechism. But he knew very little of arithmetic and nothing of grammar. He could add up two lines of figures, but could not manage the multiplication-table. He could only multiply by means of his fingers, and knew nothing of writing. He had given up bringing beasts with him to school, but he had got a bad name. One morning, when the boys were at their lessons, the master gave a loud scream, and, jumping to his feet, shook a big worm from his arm; then, turning in Tom's direction, he exclaimed, "This is some more of your work, Master Edward." Edward was then called to the floor. "You've been at your old trade, Edward, I see; but I'll now take it out of you. I have warned you not to bring any of your infernal beasts here, and now I have just found one creeping up my arm and biting me. Hold up!" Edward here ventured to say that he had not brought the beast, and he had not brought anything for a long while past. "What! a lie, too?" said the master. "A lie added to the crime makes it doubly criminal. Hold up, sir!" Tom held up his hand, and the master came down upon it very heavily with the taws. "The other!" The other hand was then held up, and when Tom had got his two hot hands the master exclaimed, "That's for the lie, and this for the offense!" and then he proceeded to bring the taws heavily down upon his back. The boy, however, did not cry.

"Now, sir," said the master, when almost out of breath, "will you say now that you did not bring it?" "I did not; indeed, sir, I did not!" "Well, then, take that," giving him a number of tremendous lashes along his back. "Well, now?" "I did not!" The master went on again: "It's your own fault," he said, "for not confessing your crime." "But I did not bring it," replied Edward. "I'll flog you until you confess." And then he repeated his lashes upon his hands, his shoulders, and his back. Edward was a mere mite of a boy, so that the taws reached down to his legs, and smote him there.

"Well, now," said the master, after he was reduced to his last effort, "did you bring it?" "No, sir, I did not!" The master sat down exhausted. "Well," said he, "you are certainly a most provoking and incorrigible devil." He ordered Tom to get his slate and books and quit the school. And with this third expulsion Thomas Edward finished his "education" at the age of about seven years.

And let us not be hard on the Scotch system of education. To be sure, the schools did but little to encourage a taste for natural history, but we have a great many pretentious educational establishments now that are not a whit in advance of them. And our state system has no place for little enthusiastic nuisances like Tom Edward. A teacher in a Brooklyn institution of high claims, thinking, not long ago, that the book "natural history" might be somewhat alleviated by a little acquaintance with the real objects about which the pupils were learning lessons, encouraged them to collect some natural-history specimens. A few cocoons were accordingly brought in, and hung up in the class-room, and watched with much eagerness until the pupils began to fear nothing would ever come of them. But one morning it was observed that a large and beautiful moth was emerging from a chrysalis, and the class became much excited with interest at the novel and curious spectacle. But for such excitement, from so strange a cause, there was no provision in the order of the school. And when the grammarian came in to take the class, they did not enter into his stupefying processes with the customary facility, at which he was so shocked that he reported his difficulty to the governing authority, and a score of the children were kept after school as a punishment for the interest they had taken in an insect metamorphosis!

School being done, young Edward went to work. He first got a place in a tobacco-factory at fourteen pence a week. Here he staid two years, having risen through the grades of responsibility until he got eighteen pence a week, but his master happened to be a bird-fancier, and favored Tom's tastes in catching animals. Leaving this place, he got a situation in a woolen-factory, at some distance from home, receiving at first three and at last six shillings a week. Besides, he got on as a night-hand, and thus had much of the day to himself for rambling in the woods, and getting acquainted with the flowers, insects, and birds. These were happy times. Tom was at the factory two years, and was then taken away that he might be bound as an apprentice to a trade. The happy genius of his father selected for him as a life-occupation the intellectual and ennobling craft of the shoemaker. He was indentured at the age of eleven to Charles Begg, who was to teach him for six years the art and mystery of making shoes, at eighteen pence a week for the first year, with sixpence a week advance each succeeding year—aprons and shoes to be supplied—time, six in the morning until nine at night; specialty, pump-making, in which Begg excelled.

Charles Begg was a low-class London cockney, and an ignorant, brutal vagabond, who had a habit of coming home drunk, of thrashing his apprentice, and then going up-stairs and beating his wife. His relation to natural history was the same as that of Tom's teachers. He had no love whatever for the works of Nature, and very naturally detested those who had. Tom had a love of birds and living creatures, and Begg hated him accordingly. If Tom brought any curiosities, Begg threw them into the street—his little boxes, with butterflies, birds'-eggs, etc. One afternoon, when Edward had finished his work, he was sitting with a young sparrow on his knee which he had trained and taught to do a number of little tricks. It was his pet, and he loved it dearly. While thus occupied the master came in drunk, and, seeing what he was doing, knocked him down, while the bird fluttered to the ground, was trampled on, and died. In this way three years passed, when one day Edward brought three young moles to the shop, in his bonnet. When Begg found them, he killed them at once, knocked down Edward with a last, seized him by the neck and breast, dragged him to the door, and with a horrible imprecation threw him into the street. Tom did not return. He wanted to be a sailor, but his father opposed it. He then ran away from home to see an uncle a long way off, who kept him all night, gave him eighteen pence, and sent him back. He had various adventures in this excursion, such as the following: He came up to three men standing in the road; two of them were gentlemen, and the third seemed to be a gamekeeper. He was showing them something which he had shot in the adjoining wood. Edward went forward, and saw that it was a bird with blue wings, and a large, variegated head. "What do you want?" said the gamekeeper to Edward. "To have a sight of the bird, if you please." "There, then!" said the gamekeeper, and thrust the bird in his face, nearly blinding him. When he got home, he tried the ships again, to go to sea, and attempted to get on board of a vessel as a "stow-away" to go to America, but could not accomplish it. So he resumed shoemaking with another and kinder employer, who did not persecute him for his love of natural things. He now started a little garden for wild-flowers, and began to prepare places for his various creatures, but his resources were too rude, and his knowledge not sufficient to succeed very well. He made tours among the booksellers to inspect the pictures in the windows, and now and then was able to buy a cheap book. He took the *Penny Magazine* and the *Weekly Visitor*, which cost but a half-penny. He was now about eighteen years old, and, the shoe-business growing flat, he enlisted in the militia for a short time, and one day, when on drill, a large, brown butterfly flitted past, such as he had never seen before, and in an instant he was off after it. After chasing it awhile, he (not the butterfly) was captured by the corporal and four militiamen, who marched him to the guard-house. The high functionaries were astounded, and pro-

nounced that he must be either mad or drunk. At the intercession of some ladies, the punishment of his heinous offense against the military majesty of his country was remitted.

When about twenty years of age Edward left Aberdeen, and went to Banff (a pleasant country town about fifty miles away, standing upon a gentle slope inclining to the sea), to work at his trade. Wages were low, and he was confined many hours in the shop, but he continued to make his natural-history collections. When twenty-three years old he married, and was fortunate in finding a woman of common-sense, who sympathized with his peculiar tastes. She had nothing, and they began to keep house on his earnings, which were 9*s.* 6*d.* per week. But he now, for the first time, had a place and room for his specimens. His education had been very limited, he could hardly write, he knew next to nothing of books, did not possess a single work on natural history, or know the names of the birds and animals that he caught. He also knew little of the nature and habits of the creatures he went to seek, or where or how to find them But he had this great advantage, that he was compelled to observe for himself, to think for himself, so that the knowledge he acquired was his own. He was modest, self-depreciating, and shy, and as his fellow-mechanics were an ignorant and brutal lot, with whom he associated very little, he was alone and friendless, which again favored the absorption of his mind in natural objects. He got compensation, for he was an intense lover of Nature, and to be in the fields, the woods, the moors, was always a great delight. When he had been married about a year, he began to make a collection of natural objects. He bought an old gun for 4*s.* 6*d.*, but it was so rickety that he had to tie the barrel to the stock with twine. This, with his powder-horn and shot-bag, a few insect-bottles, some boxes for moths and butterflies, and a book for putting plants in, constituted his equipment. He had a two-story hat, the upper chamber of which was a useful receptacle, while the crown served for sticking in and carrying his entomological pins. He carried no cloak or umbrella, and his food was a bit of bread, or a little oatmeal, which he washed down with water from the nearest spring. He never rambled on Sunday, but made it a day of rest, which was fortunate, as, without this break, he could hardly have continued his overstrained and exhausting life.

Mr. Edward had to support his family by piece-work, which occupied him from six in the morning to nine at night, and his wages were so small that he could not abridge his working-hours. But he was a man of invincible determination, and he resolved never to spend a moment idly, or a penny uselessly. Closely occupied during the day, the night was all that remained for "leisure," and that he divided between sleep and night-wanderings after animals. On returning home from his work at night, his usual course was to equip himself with his tools, and start for some one of his locations for observing. It mat-

tered little about the weather. His neighbors used to say, "It is a stormy night that keeps that man Edward in the house." He went out in fine, starlit nights, in moonlight nights, and in cold, drizzling nights. When it rained, he would look out for some hole in which he could get partial protection, and then watch for night-moving animals, insects, and birds: foxes, badgers, rats, weasels, polecats, mice, bats, owls, moths, and a host of other creatures of nocturnal habits, were the objects which he sought to observe in their ways or to obtain for his collections. It is comparatively easy to observe the habits of animals by day, but very difficult in the obscurity and darkness of night. Edward's circumstances drove him to this night-work, and soon made him expert in this peculiar line of observation. He often went out in winter, but his principal night-work was by moonlight, from spring to autumn. Seeing was of course difficult, but was greatly helped by the sounds of the midnight prowlers. In the course of a few years he learned to know all the beasts and birds of the district frequented by him. He knew the former by their barkings, gruntings, and various cries, and the latter he could identify even by the sounds of their wings when flying. He could tell the species and families of birds by their call-notes as they flew by. He would watch the fights, greetings, pranks, predacious assaults, and peculiar ways, of the midnight roamers, between snatches of sleep, and thus extended and made much more accurate one of the obscurest branches of natural history. Mr. Edward had numerous adventures in these nocturnal excursions, which are vividly related by Mr. Smiles, who also goes into much detail to illustrate the perils, exposures, and privations, of this mode of life.

Mr. Edward continued his night-researches for about fifteen years, his excursions extending for six or eight miles in different directions. He found many new specimens, and was particularly persistent in working at the birds which greatly abound in that region. He thus rapidly accumulated the objects for a collection, and after eight years had preserved nearly 2,000 specimens of living creatures found in the neighborhood of Banff, most of which consisted of quadrupeds, birds, reptiles, fishes, crustacea, star-fish, zoöphytes, corals, sponges, and other objects, together with an immense number of plants. He placed these in cases, which he made himself by the aid of a shoemaker's knife, a saw, and a hammer. He stuffed his own birds, and mounted all his own objects. Of course, he was not exempt from the accidents to which such material is exposed. He had deposited twenty boxes, containing 916 insects, in his garret, and when he went to fetch them he found they had been all eaten by the mice, the pins only remaining, with here and there a head, leg, or wing. On another occasion, having put 2,000 preserved plants in a box which was carefully placed out of harm's way, when he went to overhaul them he found that the cats had made their lair in the box and ruined the whole collection.

There was an annual fair at Banff, and in 1845 Edward resolved to exhibit his collection. So he brushed up his specimens, cleaned his cases, of which he had about 300, and exhibited them, or rather had them placed on exhibition, at Trades Hall. He made a small charge for admission, and received quite a number of visitors. It took the inhabitants by surprise, and they began to understand him; his strange night-wanderings having been a matter of much wonderment and mystification to the people of the town. He got a little money and without much expense by showing his collection, and, being very anxious to turn himself in some way so as to get relief from the drudgery of the shop, and acquire time and means for more devotion to his favorite pursuits, he formed the perilous resolution of trying Aberdeen as a place of exhibition. This city was the old centre of northern intellect, cultivation, wealth, and business, with two universities, filled with professors and students, and a large, intelligent, and thrifty population. Edward got his collection into six carrier's carts—there being no railroads—and started out with his wife and five children July 31, 1846, reaching Aberdeen on the evening of the following day. He took a shop, advertised, and scattered handbills. Terms of admission, "Ladies and gentlemen, 6*d.*; tradespeople, 3*d.*; children, half price." The *Aberdeen Journal* thus noticed the collection: "We have been particularly struck with the very natural attitudes in which the birds and beasts of prey are placed; some being represented as tearing their victims, others feeding their young, and some looking sideward or backward, with an expression of the eye which indicates the fear of interruption. The birds are very beautiful, and the entomological specimens will be found exceedingly interesting." Edward expected a rush, but he was disappointed. But very few persons called to see the collection, and these were chiefly stuffed-bird dealers, who wanted to sell him specimens, or knaves with counterfeit monstrosities to dispose of. Some ladies called, to consult him about sick lapdogs, diseased cats, and a broken-legged pig. One gentleman wished him to come and cut off the front teeth of an old and favorite rabbit, as they had grown so long that he could not eat; but only very few came to see the collection, and of those who did come none could be made to believe that the specimens were all collected and prepared by a man who had to work all day to support his family. Professors of the university came and told him that the inhabitants of Aberdeen were not yet prepared for an exhibition of this kind, though the reader will observe that the incorporated town was seven hundred years old and contained sixty churches, while its university had been operating on the Aberdonian mind for two centuries and a half! The fact is that, notwithstanding all its "culture," Aberdeen was no more appreciative of a true lover of Nature than Tom Edward's teachers had been; and he went out of Aberdeen in much the same way that Begg pitched him out of his shop. He got in debt, became discouraged and

half distracted at his situation. More advertising only aggravated his trouble. After a month he had lost hope, and, what was worse, his master at Banff wrote him that if he did not immediately return he would lose his place. He became despairing, and started for the seashore with a view of putting an end to his troubles. He had thrown off his hat, coat, and waistcoat, before plunging into the sea, when a flock of sanderlings lit upon the sands near him, and among them a larger and darker bird, that he was not acquainted with. They flew, and he followed them, again and again, until he exhausted himself, and worked off his misery. Nothing remained but to sell his collection, which he did for twenty pounds to a gentleman who wanted it for his boy. These specimens were stored in a damp room, and eventually perished; but the exhibitor got out of debt, and went back with his family to Banff.

Edward felt crushed and ruined when he got back to his home. He had not only lost the precious fruits of many years of loving labor, but his hopes of anything for the future but slavery in the shop were blighted, and his life looked dark and desolate. He resumed work, but at first had little spirit to begin replacing his lost specimens. Yet, as spring advanced, his passion again took possession of him, and he girded himself with his gun and insect-boxes and various appendages, and again sought his old haunts of observation. His zeal and perseverance were now greater than before. His friends protested that his exposures were wearing him out, but he says: "One look at my cobbler's stool dispelled every consideration. My wish was, at some time or other, to wrench myself free from my trade." He now improved his outfit by getting a coat with eight large pockets, and had four ample receptacles in his waistcoat; besides, he had a number of bags and wallets geared for convenient carrying, and all were stocked with facilities for advancing his work. On one occasion, after a prolonged tour, and when all his boxes and cases were filled with insects and worms of every sort, he was caught in a terrific thunder-storm, and soaked through and through by the rain. He reached a house at length and sought shelter, but the glue of his boxes had softened by the water, and, coming apart, let out the ants, worms, slugs, spiders, and caterpillars, so that he was completely covered with miscellaneous vermin. The woman of the house yelled at him: "Man, fat the sorra brocht ye in here, an' you in siccan a mess? Gang oot o' my hoose, I tell ye, this verra minit! Gang oot!" On looking at his clothes he found that he was a moving mass of insect-life and creeping things, and he cleared the room at a bound and took refuge in an old shed.

After his exhibition at Banff, he became a sort of general referee in regard to all curious objects found in the district, and got a great deal of advice as to what he ought to do, but nobody offered to help him. He had a family of eight, and his wages, even with extra work,

were but fifteen or sixteen shillings per week. His wife helped him efficiently; she bound shoes, and received separate pay for it, but she would often with her own earnings buy bottles for his insects, wood for his bird-cases, powder and shot for his gun. None of his advising friends ever helped him in this way.

His expeditions were often accompanied by dangerous adventures. On one occasion, as he was coming home in the morning, he shot a martin, which fell upon the edge of a cliff. He clambered to the spot, and, just as he was seizing it, it fluttered over, and in trying to grasp it he went over himself. His gun fell out of his hand, and lodged across two rocks. Edward came down upon the gun, smashing it to pieces, but it broke the force of the blow, and probably saved his life. He had descended forty feet, and was wedged in between two rocks, where he remained senseless until with great difficulty he was extricated by two ploughmen and a fisherman, terribly sore and bruised. He got home, but was unable to work, and had to sell more of his collections to meet family expenses.

Shortly after his return from Aberdeen, Edward made the acquaintance of the Rev. James Smith, who lived about eight miles from Banff, and who lent him some books that helped him to ascertain the names of birds, and Mr. Smith also urged him to publish the results of his observations. Edward replied, "I cannot write correctly enough for the publishers." "But you *must* write," said Smith. "You must note down your observations." Edward objected much, but he nevertheless took to the work, and soon developed unusual descriptive power. He wrote articles, from time to time, for the *Banffshire Journal*, on various interesting objects, which had the effect of directing general attention to natural-history subjects. Further encouraged by his friend Smith, he began to write for the *Zoölogist*, giving an account of his discoveries, and of those habits and peculiarities of animals which he had closely observed. At the end of 1855 we find an article of his in the *Zoölogist*, entitled "Moth-hunting, or an Evening in the Wood," and in the following year he commenced in the same periodical a "List of the Birds of Banffshire, accompanied with Anecdotes." This list comprised eight articles, which were received with much favor, yet he never got a farthing for any of his literary contributions!

It is worth while to note how he could write. He printed in the *Banffshire Journal* an account of a very dangerous adventure he had by getting trapped in the recess of a cliff from which there seemed to be no possibility of escape in any direction. He says: "I sat down to consider what was next to be done. While thus resting, I observed a falcon (*Falco peregrinus*) sailing slowly and steadily along, bearing something large in his talons. On he came, seemingly unconscious of my presence, and alighted on a ledge only a few yards from where I sat. I now saw that the object he carried was a par-

tridge. Having fairly settled down with his quarry on the rock, I could not help wondering at and admiring the collected ease and cool composure with which he held his struggling captive (for it was still alive) until death put an end to its sufferings. There was no lacerating with its beak at the body of the poor and unfortunate prisoner, in order, as it were, to hasten its termination; no expanding of the wing to maintain his equilibrium, although the last and dying struggle of the bird caused him to quiver a little. All being over now, with one foot resting upon his game and the other on the rock, silent and motionless as a statue, the noble captor stood, with an inquiring eye, gazing at the now lifeless form of his reeking prey, seeming to doubt the fact that it was already dead. But there was no mistake. The blood, oozing from its mouth and wounds, its body doubtless pierced by the talons of the conqueror, already began to trickle down the sides of the dark cliffs, dyeing the rocks in its course. Satisfied at last that life was fairly extinct, an incision was then made in the neck or shoulder of the victim, and into this the falcon thrust his bill several times, and each time that it was withdrawn it was covered with blood. This being done, and having wrenched off the head, which he dropped, he then began not only to pluck but to skin his food from the neck downward; and, having bared the breast, commenced a hearty meal by separating the flesh from the sternum into portions, with as much apparent ease as if he had been operating with the sharpest surgical instrument. I should have liked well to have seen the end of the work thus begun; but, unfortunately, a slight movement on my part was detected by the quick eye of the falcon, and my nearness was discovered. Having gazed at me for a few, and only for a few, seconds, with an angry and piercing scowl, mingled with surprise, he then rose, uttering a scream so wild and so loud as to waken the echoes of the surrounding rocks; while he himself with the remains of his feast, which he bore along with him, rounded a point of the cliff and disappeared; and there is no doubt that he ended his repast in unmolested security."

In 1854 Edward lost his valued friend Smith, by death, and he mourned for him very deeply, as he was a man of wide culture, and with a thorough appreciation of the character of Edward. Mr. Edward was under the impression that people looked down upon him and his work, because he was a poor shoemaker, and in this, of course, he was right. But the clergyman treated him as one intelligent man treats another. His loss, however, was greatly repaired by the acquaintance of the Rev. Mr. Boyd, of Crimond, a few miles off, also a naturalist, who had a high and appreciative regard for him. The two clergymen had made various efforts to secure for Edward some position in which he could live and give freer play to the bent of his genius. But they failed. Mr. Boyd once proposed that Edward should get up a series of rudimentary lectures on natu-

ral history, illustrated by specimens of birds and other objects. They were to be given first in Banff, and then in other places. Edward got his illustrations ready, and the project looked feasible. There existed in the town of Banff an institution which had been formed, among other purposes, "*for the discovery and encouragement of native genius and talent.*" What could be more promising? Mr. Boyd believed that they would heartily coöperate in the lectures, because it would be in accordance with the avowed purpose of the institution. Several members were applied to, to give their assistance, but they politely declined, and the scheme fell through. Shortly afterward Mr. Boyd died, and Edward was deprived of another efficient friend. "Another of my best friends is gone," exclaimed he. "Cruel Death! if thy hand continues to strip me thus, thou wilt soon, very soon, leave me desolate; and then who will take notice of the poor naturalist?"

At last, his health gave way altogether, and he had a long attack of rheumatic fever; and again his collections had to be sold, to protect the family from want. He now lost all hope of ever being able to replenish them. He had to abandon his night-wanderings, but he turned to the natural history of the sea-shore. Here he had a new field, and worked with great success. He discovered many new species of marine creatures, and greatly extended the knowledge of the habits and history of those already known. His daughters gave him very valuable assistance in many ways, especially in searching the fish-markets along the shore. Mr. Edward was, moreover, now beginning to be better known to naturalists, who sought his correspondence and his aid, and among these were Spence Bate, Westwood, Couch, and Gwin Jeffreys. Bate tried to get a place for him in a scientific institution, at thirty shillings per week, but it turned out to be a fourth portership at one pound per week, and could not be got even at that. Edward's hopes were once more blighted, and nothing remained for him but the cobbler's stool. He tried photography as a means of living, but was not able to provide a glass-window department, and failed in that also. The fact is, he was simply a born naturalist, made for the discovery of the things of Nature, and, if his Christian country had been half civilized, he would have been kept at that priceless work for which so few men are gifted by rare original endowments.

We can hardly refer to, much less enumerate, the achievements of Edward in many departments of observation, which are described with great felicity by Mr. Smiles. At the close of his volume he gives selections from the mammals, birds, fishes, and crustacea, with which this man enriched the fauna of Banffshire; but while the list comprises many hundred, in a long appendix, the author states that, if all were given, they would fill a volume. Among the crustaceans alone, of two hundred and ninety-four, found in the Moray Firth, not fewer than twenty-six new species were added by Edward himself.

But Edward's scientific labors drew toward a close. He had fought the fight of science on the one hand, and of poverty on the other, until his constitution, strained by exposure and battered by accidents, was no longer equal to the double struggle. In 1866 he was elected an associate to the Linnæan Society, one of the highest honors that science could confer upon him, and he was shortly after also made a member of the Societies of Natural History at both Aberdeen and Glasgow. His biographer states that since then he has been able to do comparatively little for the advancement of his favorite study.

In June, 1875, Edward remarked: "As a last and only remaining source" (of subsistence), "I betook myself to my old and time-honored friend, a friend of fifty years' standing, who has never yet forsaken me, nor refused help to my body when weary, nor rest to my limbs

"And here I am still."

when tired—my well-worn cobbler's stool. And here I am still on the old boards, doing what little I can, with the aid of my well-worn kit, to maintain myself and my family; with the certainty that instead of my getting the better of the lapstone and leather, they will very soon get the better of me."

It remains only to add that, since the publication of Mr. Smiles's book, the queen has been moved to grant Thomas Edward a pension of fifty pounds a year. All will be glad of this; but we cannot forget that if this man had directed his genius to the work of war, with a tithe of the success he has achieved in enlarging our knowledge of Nature, his reward would have been far greater than it is now!

CORRESPONDENCE.

SPENCER'S CLASSIFICATION OF THE ABSTRACT SCIENCES.

To the Editor of the Popular Science Monthly.

I AM a great admirer of Herbert Spencer, and especially of his wonderful "Answers to Criticisms" in your journal. When he seems entirely caught and inwoven by his adversaries, with one blow of his trenchant blade he cuts the net, and is free.

He is one of the highest of living authorities, and I read with deep attention his two editions of "The Classification of the Sciences," being particularly interested in Table I., "The Abstract Sciences." All of it but two divisions he devotes to mathematics as exactly equivalent to quantitative relations; still, at the present day, it seems an untenable cramping of mathematics to define it as the science of quantity.

A candid note in Mr. Spencer's first edition shows that it was not till after he had actually drawn up this table that he became aware of one of the most important points in the question to be solved.

It is a note to his first great division of mathematics, and says: "I was ignorant of the existence of this as a separate division of mathematics, until it was described to me by Mr. Hirst, whom I have also to thank for pointing out the omission of the subdivision 'Kinematics.' It was only when seeking to affiliate and define 'Descriptive Geometry' that I reached the conclusion that there is a negatively-quantitative mathematics as well as a positively-quantitative mathematics."

All this confession is omitted in the second edition, where, however, the much superior expression "Geometry of Position" is substituted in the table for "Descriptive Geometry," which latter was very apt to be misleading, especially to engineers, from its technical sense, in which sense, of course, Spencer did *not* mean it.

Now let us try to explain, in few words, what the problem was that Hirst so unexpectedly put before Spencer's mind, that you may judge whether "seeking to affiliate" it to a scheme already drawn up was a proper mental condition in which to deal with a question so important, so subtile, so profound.

Geometry, as the abstract science of space, naturally resolves itself into two great divisions, geometry of measurement and geometry of position—geometry quantitative or metrical, and geometry morphological or positional.

As an example of the first, we may take the most ordinary illustration, that of equivalent triangles. Any two triangles having the same base, and their vertices in a line parallel to that base, will be of equal or "equivalent" superficial magnitude. Although the sum of the three sides of the one triangle might be a thousand times as great as the sum of the three sides of the other, they will contain the same number of square inches or square feet. This is a metrical or quantitative proposition; but, on the other hand, many propositions are known which are purely descriptive or morphological. Take the one, perhaps, best known, the celebrated hexagram.

In any circle join any six points of the circumference by consecutive straight lines in any order: the intersections of the three pairs of opposite sides are in a straight line. Or, take any two straight lines in a plane, and draw at random other straight lines traversing in a zigzag fashion between them, so as to obtain a twisted hexagon or sort of cat's-cradle figure: if you consider the six lines so drawn symmetrically in couples, then, no matter how the points have been selected on the given lines, the three points through which these three couples of lines respectively pass will lie all in one and the same straight line. So great an authority as Prof. Sylvester has stated that this proposition "refers solely to position, and neither invokes nor involves the idea of quantity or magnitude." Take another: If any pencil of four rays is cut by a transversal, any anharmonic ratio of the four points of intersection is constant for all positions of the transversal.

Now, Carnot in his splendid "Geometry of Position," and many before and after him, have laid open a whole world of truths of this kind, truths undeniably geometrical in their nature, but founded on the primitive idea of position, and bringing in any idea of quantity only incidentally and afterward. Now, this was evidently a branch of mathematics, but, having made his scheme mathematics only coextensive with quantitative relations, Herbert Spencer must force this under the quantitative rubric, and thus was betrayed into error. Seeing that it was not really positively quantitative, he could only call it negatively quantitative, but in doing this entirely misrepresents it. In Table I. he has, under "Abstract Science:"

"Laws of Relations

that are Quantitative (Mathematics).

"Negatively: the terms of the relations being definitely-related sets of positions in space, and the facts predicated being the absence of certain quantities ('Geometry of Position')."

Now, we contend that there is naturally nothing negative about the matter, and to call it negative is unfairly to wrest it from its proper simplicity in order to force it under a preconceived classification. The primitive and natural idea of position is of any portion of space, as distinct from space in general, and does not depend at all upon any quantitative relations, either positive or negative. But, after this, if we wish to define any position with reference to any other definite known position, we use quantities, coördinates, and by this means we can, by using only positive quantities, e. g., a positive straight line and a positive angle, accurately refer any one point in any plane to any other point in the same plane.

So "the proposition that certain three lines will meet in a point" is not "a negatively-quantitative proposition," as Spencer asserts in his note. It is primarily not quantitative at all, but positional; and, secondarily, if one wishes to look at it in a quantitative light, it is then very positively quantitative, since it asserts that the three lines will run together on a point which may be exactly fixed by positive quantities—its polar coördinates; or, having the point fixed by the intersection of either two of the lines, it asserts, *directionally*, that the third line must go directly through that point. In the same way, the assertion that "certain three points will always fall in a straight line" is primarily an assertion of relative position, in which the relation is defined in the simplest manner by a single positive straight line. The whole question is this: Is not position as simple and primitive an idea as quantity? and is not Spencer in error when he gives its abstract science no separate place, but ranges it under, and tries to make it depend upon, quantity?

George Bruce Halsted, A. B.,
Mathematical Fellow of Johns Hopkins University, late Mathematical Fellow of Princeton College, Intercollegiate Prizeman.

P. S.—Since the above was in print, I have noticed that Arthur Cayley holds views on this subject very much opposed to those of Mr. Spencer. (*See* Cayley's "Sixth Memoir on Quantics," in the "Philosophical Transactions.") G. B. H.

It has been remarked of Mr. Herbert Spencer that he does not stand well with the experts—men trained in specialties, and who know their subjects at first hand, and through and through. This is thought to be a formidable charge, and it would be formidable if it were true, and the experts agreed among themselves. But when they coincide in nothing but in differing from Mr. Spencer, we may be moderately reassured, and venture to think upon the questions they raise, without the sense of being crushed to the dust by the weight of authority.

This is not the first time that Mr. Spencer's note, or, as our contributor calls it, his "confession," has been attacked by mathematicians, and in such a way as to admonish him that, as this world is constituted, it is not always wisest to be very candid. It has ever been a rule with him carefully to acknowledge the aid he has received from others—a practice which, as in the present instance, has exposed him to misunderstanding and misrepresentation. Mr. Halsted recognizes that, by "Descriptive Geometry," Mr. Spencer did *not* mean those technical methods of geometrical construction to which engineers apply the name; yet no less a mathematical expert than Mr. Chauncey Wright—the pride of Cambridge, and whose biography we are soon to have—attacked him a dozen years ago, in the *North American Review*, on the very passage here dealt with by Mr. Halsted, but on the opposite ground that such *was* Mr. Spencer's meaning of Descriptive Geometry. And having assumed that Spencer meant a mathematical art which he was trying to classify as abstract science, Wright insinuated that by his acknowledgment to Hirst he was ignorant even of this. It was a disingenuous piece of work. Mr. Wright was then hunting through Spencer's various books in search of flaws to work up into a sensational article, and he was not very particular how he did it, so he could make a telling point. As his note was liable to such misconstruction, Mr. Spencer very naturally withdrew it in a second edition, and substituted for the title first used one less liable to be misunderstood.

And now has not Mr. Halsted also somewhat misapprehended this memorable note? If Mr. Spencer was not referring to the art of Descriptive Geometry, as Mr. Halsted admits he was not, then he must have been referring to the system of theorems in the science of pure mathematics which has

grown up under the name of "Descriptive Geometry." But where is the evidence that he was ignorant of these theorems? He certainly does not say that he was made acquainted with them by Mr. Hirst, but simply that he was first informed by him that they had been grouped into "a separate division of mathematics." Why he did not know of this is readily explained, as the title Descriptive Geometry had never been adopted in England for the subject to which it had been applied, from Monge, to Reye on the Continent; and its modern restricted use was very naturally known only to professed mathematicians. What Prof. Hirst put before Mr. Spencer was, therefore, not any new mathematical problems or principles which he found it necessary as an afterthought to thrust into a previously-formed mathematical philosophy, but only the recognized differentiation of a certain mathematical province.

As for the non-quantitative mathematics, we fail to see that Mr. Halsted gets up much of a difference with Spencer. Mr. Halsted thinks that the "Geometry of Position" does not involve the notion of quantity, and Mr. Spencer thinks the same. But the experts of "Harvard" and of "Johns Hopkins" are squarely at issue on this point. After making his case against Mr. Spencer on a false interpretation of what he said, Mr. Wright admitted that, perhaps, after all, he did not mean that—possibly, instead of a branch of the engineer's art, Spencer was referring to "certain propositions in the higher geometry concerning the relations of position and direction in points and lines." But he opens a battery of sarcasms upon the idea of non-quantitative mathematics, and says of these geometrical propositions that they "cannot be made to stand alone, or independently of dimensional properties." Spencer was thus attacked by a skilled mathematician a dozen years ago for taking substantially the same ground that Mr. Halsted now advocates.

In regard to the terminology of the subject, Mr. Halsted encounters the difficulty which always arises when knowledge outgrows old definitions. No doubt, if positional geometry is non-quantitative, and is still a branch of mathematics, we should have a new definition of mathematics; but it is much easier to discredit the old one than to replace it by a better. Why does Mr. Halsted continue to apply the term geometry, which, by its very structure and etymology, implies measure and quantity, to that which has no quantity? Mr. Spencer evidently saw the difficulty; but, rather than attempt to redefine mathematical science, he preferred the alternative of marking off the newly-recognized province by a title that excluded the element of quantity—that is, he called it negatively quantitative. Mr. Halsted does not like this term. Speaking of a certain proposition given as an illustration by Spencer, he says: "It is not 'a negatively quantitative proposition,' as Spencer asserts in his note. It is, primarily, not quantitative at all." But what does Mr. Halsted suppose Mr. Spencer means by "negatively quantitative," unless he means not quantitative at all, or the denial and exclusion of quantity? Let us observe exactly what Spencer says: "In explanation of the term 'negatively quantitative,' it will be sufficient to instance the proposition that certain three lines will meet in a point, as a negatively-quantitative proposition, since it asserts the *absence* of any quantity of space between their intersections. Similarly, the assertion that certain three points would always fall in a straight line is 'negatively quantitative,' since the conception of a straight line implies the *negation* of any lateral quantity or deviation." The italics are ours, but the statement is sufficiently explicit. The absence or negation of quantity is as strong an expression as could be used for no quantity at all, or that which Spencer calls negatively quantitative. Mr. Spencer designates the "Geometry of Position" as of this kind, and yet Mr. Halsted imputes to him the error of ranging it under and trying to make it depend upon quantity.

Mr. Halsted reports that, in his last bulletin, Cayley stands opposed to Spencer's views. It is to be hoped that he understands him; but what is his relation to Wright and Halsted?

And now, apologizing to our readers for introducing this remote discussion, and passing it off under the head of popular science, we call upon the heirs and repre-

sentatives of Johns Hopkins to hurry up their proposed *Mathematical Journal*, that there may be a proper place for the consideration of questions like this.

INSECTS AND FLOWERS IN COLORADO.

To the Editor of the Popular Science Monthly

The communication of Mr. Meehan, in your January number, and the request at its close, are herewith responded to by the entomologist in question—one to whom we may fairly apply the line—

"[Though] young in years, in sage experience old."

As the letter supplies the information called for, you will, doubtless, wish to print it in full, and I inclose it for that purpose.

Very truly yours, Asa Gray.

Cambridge, Mass., *January* 22, 1877.

Dear Dr. Gray: In the January number of The Popular Science Monthly, Mr. Meehan takes some exception to your note in the *American Journal of Science* for November in regard to the comparative abundance of insects and flowers in the Rocky Mountains of Colorado. He asks particularly for a "list of the *Hymenoptera* and *Lepidoptera* that are abundant enough in the particular part of the Rocky Mountain region covered by [his] experience, to probably act as cross-fertilizers of flowers, noting those which may perhaps be introduced since 1871." The route referred to is "through Golden City and Idaho Springs to South Park, thence to Pike's Peak and the Garden of the Gods. . . . to Denver over the level plateau known as the 'Divide.'" In 1873 he speaks of having visited Gray's Peak, and must, therefore, have passed up Clear Creek and through Georgetown. In 1872 I spent three months in the mountains of Colorado in company with Dr. C. C. Parry. We walked up through the cañon of Clear Creek to Idaho Springs, Georgetown, and Empire City. At the latter place we established our headquarters, and there most of my collecting was done. Frequent trips were made to the neighboring mountains and cañons, including the ascent of Gray's Peak. In the fall a trip was made to Middle Park. The summer of 1873 I spent in Western Wyoming with Captain Jones's exploring party. In 1874 I again visited Colorado, but spent most of my time on the plains at the base of the mountains between Boulder City and Cañon City, though I made several trips into the mountains up Boulder, Left Hand, and Clear Creeks. In 1875 I spent some time in Utah among the Wahsatch Mountains. It has always been my experience that, wherever flowers were plenty, so were insects. Consequently, I have always found a botanist to be most excellent company on a collecting-trip. As my opportunities were better in 1872, my remarks refer mostly to that year, and it is not at all likely that any of the species I then noticed had been introduced. Lists of the *Coleoptera*, *Lepidoptera*, *Hymenoptera*, and *Orthoptera*, collected on this trip, have been published in the "Proceedings of the Davenport Academy of Natural Sciences," vol. i.; but I will here call attention to such of the species as seem to be most useful in the fertilization of plants:

Hymenoptera.—*Bombus flavifrons* (Cr.) was perhaps the most common and generally distributed of the bees, though it seems to be quite a mountain species. I always found it wherever there was a patch of flowers in an opening in the timber, or at the timber-line. I did not notice that it confined itself to any particular kind of flower. It may have done so, but I do not remember it. In company with the above, though somewhat less abundant, I found *B. ternarius*, the species mentioned by Mr. Meehan as confining its attention to *Polygonum bistorta*, but I did not notice this peculiarity. Both of these species were found abundantly at Empire City and on the surrounding mountains. Besides these, *Bombus borealis* (Kirby), *Apathus insularis*, *Anthophora terminalis*, *Megachile gentilis*, *Monumetha borealis*, were found in abundance in the district referred to by Mr. Meehan. Of other *Hymenoptera* collected in this district, I mention the following, which probably were of more or less assistance in the fertilization of plants: *Calliopsis* (sp.?), *Prosopis affinis*, *Agapostemon texanus*, *Colletes consors*, *Vespa diabolica*, *Ammophila luctuosa*, *A. communis*, etc., besides a considerable number of smaller species as yet undetermined. For a more complete enumeration, I must refer you to the list above mentioned. To

show that I am not the only one who has noticed an abundance of *Hymenoptera* in Colorado, I would call your attention to the papers of Mr. E. T. Cressen in the "Proceedings of the Entomological Society of Philadelphia," and particularly to a "Catalogue of *Hymenoptera* from Colorado Territory," published in vol. iv. of those "Proceedings."

Lepidoptera.—In the list referred to I have enumerated forty-seven species of butterflies, which I collected, with but one exception, in the mountains. I have never anywhere seen butterflies so abundant as they were in the valley of Clear Creek, between Golden City and Idaho Springs, on July 1, 1872. The air seemed literally to swarm with them. I cannot imagine how the entomologists of Mr. Meehan's party found them so scarce. Wherever there were flowers, I was sure to find butterflies, though, of course, they showed a preference to some kinds. Of the *Heterocera* I brought home over sixty species, mostly undetermined; but this is no indication of the actual number occurring, for I took no pains to hunt them, and only preserved what came to me.

The common morning lined sphinx (*Deilephila lineata*) was frequently seen at dusk, hovering about various flowers, being especially fond of the yellow thistles. I do not now recall any peculiarity regarding the other species, except that they were quite plenty. Perhaps 1872 was an unusually favorable season; but Mr. Theodore L. Mead writes that in 1871 he spent four months in Colorado, mostly in the South Park region, where he collected over 100 species and 3,000 specimens of butterflies, and 4,000 specimens of beetles, etc. I believe Mr. Mead has published an account of his observations on Colorado butterflies in the zoölogical report of Lieutenant Wheeler's explorations west of the 100th meridian. I would also refer you to an article on Coloradian butterflies, by Tryon Reakirt, in the "Proceedings of the Entomological Society of Philadelphia," vol. vi., 1866, and to the more recent works of W. H. Edwards, and others.

Although Mr. Meehan does not mention them, I have an idea that the *Coleoptera* and *Hemiptera* are often quite active agents in the fertilization of plants. Certainly the number of species of these orders found in flowers was very great, and it is more than likely that in going from flower to flower they carry some of the pollen with them. The *Meloidæ*, *Chrysomelidæ*, *Cerambycidæ*, *Cleridæ*, *Malachidæ*, *Mordellidæ*, etc., were especially noticeable by the large number of species and individuals. *Trichodes ornatus* (Say) was exceedingly abundant in the flowers of *Potentilla fissa*, and, after that had generally gone out of flower, on the flowers of the white and red geraniums and other plants. Owing to the fact that at the time I made these collections I knew the names of neither the plants nor insects, I cannot now remark more definitely on their habits. A full list of the species collected will be found in the "Proceedings of the Davenport Academy," vol. i.

I think what I have said shows that there is no unusual scarcity of insects in the Rocky Mountains of Colorado, at least wherever there are flowers. It should not be overlooked, however, that within the Rocky Mountain regions there are arid districts where neither insects nor flowers are particularly abundant; and also that a similar state of affairs exists in a dense pine or spruce forest. Wherever flowers are plenty in the Rocky Mountains, so are insects always; but the reverse is often not true, for I have frequently known certain insects to be exceedingly plentiful where there were no flowers. The "entemologists" of Mr. Meehan's party were certainly very unfortunate in finding so few insects. I believe Mr. Morrison, of Cambridge, an excellent collector, intends spending next summer collecting the insects of Colorado, and he will be able to add his testimony to the case.

Mr. Meehan has certainly read Lieutenant Carpenter's paper in Hayden's Report for 1873 very carelessly, or he would have seen that the five species of butterflies he speaks of as being the "doings of a whole season" were all Alpine, and collected above the timber-line, a region which a little further on he rules out of the discussion. It is certainly true that these *Alpine* "*Lepidoptera* are undoubtedly peculiar to high latitudes and great elevations;" but

the species found lower down in the cañons often show a greater affinity to Mexican and Californian types. I was more fortunate than Lieutenant Carpenter, and took over twenty species of butterflies above the timber-line.

I have endeavored to show that sometimes at least insects are quite plentiful in the Colorado mountains. They are certainly more plentiful in the mountain-regions than on the plains.

Yours very truly,

J. Duncan Putnam.

Davenport, Iowa, *January* 10, 1877.

EFFECTS OF THE WAR ON THE INCREASE OF POPULATION IN THE LAST DECADE.

To the Editor of the Popular Science Monthly.

The Superintendent of the Ninth Census, while showing the causes of loss in population produced by the late war, neglected to point out the actual decrease incident to this cause, as shown by the State censuses of 1865.

The retarding influence may be seen by reference to the States of New York and Massachusetts.

In the former State, whereas the regular increase for each period of five years had been nearly 500,000, from 1860 to 1865 there was a *decrease* of 29,000. From 1865 to 1870 there was an increase of 529,000.—("Manual" for 1870.)

In Massachusetts the increase of population from 1850 to 1855 was 138,000; from 1855 to 1860 it was 90,000; from 1860 to 1865, 36,000; from 1865 to 1870, 190,000; and from 1870 to 1875, 194,000. The regularity of increase in the State is shown by the fact that the difference between the actual population in 1870 and that computed on the supposition that the increase was in arithmetical progression was only 2,120.—("Massachusetts State Census" for 1875, vol. i., p. xxxii.)

In these two States, therefore, the increase of population during the war-period was only 7,000, while in the next five-year period it was fully a hundred times as great. The population of these two States was over 6,000,000, or more than fifteen per cent. of the total population of the United States.

As it may be urged that these States suffered heavily in loss of immigration, we will attempt to estimate their actual loss in this respect. The total loss of immigration is estimated ("Ninth Census," vol. i., p. xix.) at 350,000. If we suppose the immigration into a State to be proportionate to the foreign population of that State, the proportion of loss in immigration for these two States will be 27 per cent. of the whole loss, or about 94,500. Omitting the loss in immigration, therefore, the total gain of these two States will be 101,500. Even if we further suppose that these States suffered another special loss of 48,500, the total gain would still be only 150,000. Multiplying this by 8, the ratio between the increase of population in these States (700,000) from 1865 to 1870, and the estimated increase of the United States for the same time, we get for the total gain of the country, without considering the loss in immigration, 1,200,000. Deducting this loss, we have for the entire gain 850,000.

We have no reason to suppose that New York and Massachusetts were especial sufferers during this period. Many of the Southern States probably suffered more, especially in loss of negro population, which amounted to half a million during this period ("Ninth Census," vol. i., p. xviii.). There is, then, no reason to suppose that the above estimate falls far short of the truth. Even if the estimate is increased to 1,500,000, which seems improbable, the population of the country in 1865 would still fall short of 33,000,000. This would indicate for the succeeding period of five years an increase of 5,500,000, which is somewhat above the average. That this large increase is actual is rendered probable by the corresponding large increase in Massachusetts and New York for the same time.

Alexander Duane, *Union College.*

EDITOR'S TABLE.

BIOLOGY IN COMMON SCHOOLS.

WE call attention to the important paper sent to us by Prof. Huxley, on the study of biology. Science, as the highest expression, and the most accurate and methodical form of knowledge, is pressing its educational claims; and Prof. Huxley here offers us some very important considerations on the nature of biological science, and why and how it should be taken up in institutions devoted to mental culture. Perhaps no living man can speak with more authority upon this subject than Prof. Huxley, not only from his profound familiarity with this branch of knowledge, and his recognition of the demands of scientific education, but because of his own broad and liberal culture, which protects him from narrow views, and enables him to assign their relative values to different branches of study.

Nevertheless, when he comes to his fourth and final question as to "*when* biological study may be best pursued," we think he is less satisfactory than in dealing with his previous questions. This, as we look at it, is much the most important inquiry, and deserves a fuller investigation than Prof. Huxley had time to give it; while what he did say, from the use that will inevitably be made of it, will be liable to do more harm than good. Prof. Huxley is decided in the conviction that biological study should be made a part of ordinary school-training, and that it can be carried out with ease and profit to those who are taught. But he anticipates and yields to an objection which, as things are, will be certain to work the utter defeat of the study in "ordinary schools," and an objection, to the force of which, we think, he should not have made the slightest concession. He says, "There are difficulties in the way of a lot of boys making messes with slugs and snails." Prof. Huxley has here put his finger upon what is the formidable obstacle we have to encounter in the study of the real objects of Nature in common schools. Books, lessons, and recitations, are cleanly, and give no trouble; objects as matters of observation and study by individual pupils are dirty, cluttering, and untidy, if not messy, sloppy, and nasty. Experiments are tolerated, now and then, for an hour, when carried on by the teacher at one side, behind tables, or where assistants can clean up; and minerals and specimens are also allowed when they can make a show in inaccessible cabinets; but apparatus and objects of any sort, for the use of individual pupils — even microscopes, minerals, or plants—are the bore of the school-room, and the torment of tidy, methodical, and routine teachers. The superstition that education is purely a matter of books is profound and inveterate—so much so, that even the employment of blackboards, maps, and globes, is looked upon as something in the way of concession to the spirit of modern innovation. The ideal of the school is pure wordiness, with a minimum of bother from anything not included in the text-books.

As regards biology, of course, the difficulty takes its most aggravated form. There is a deeply-rooted and universal prejudice against the whole tribe of lower creatures, typified by Prof. Huxley's "slugs and snails." Our readers who have glanced at the biographical sketch, in the preceding pages, of an eminent Scotch naturalist, who has done noble work for science in his locality, will remember that he

was turned out of three schools before he was seven years old, in consequence of his irrepressible passion for collecting the curious natural objects which fell in his boyish way. But the feeling which led to the treatment of little Tom Edward is far enough from being confined to his brutal and besotted teachers. We have seen cultivated, high-school instructors, and parents claiming to be liberal and intelligent, who would cry out with horror to see their children touch such repulsive things as worms and frogs, and threaten them with a thrashing if they brought them in or around the house. It is this vulgar and absurd prejudice that stands in the way of anything like rational biological study in our schools. Undoubtedly, it is very nice and pleasant to learn natural history out of text-books full of pictures, and abounding in pretty anecdotes about animals; but we can only get the study, in place of this, of actual living creatures by battling with and conquering the foolish infatuation of people in regard to the repulsiveness of the inferior forms of life. Unperverted children are fond of them, and this feeling should be cherished and encouraged, and made available as an impulse in early study. Prof. Huxley knows how to deal telling blows at the various pestilent bigotries of society that stand in the way of its intellectual progress; and we should have been better pleased if he had denounced this prejudice as it deserves, rather than make tacit terms with it, as a "difficulty," because progress is only made as difficulties are overcome and got out of the way.

As to human physiology, we doubt if it is the proper door to biology, either for young or old—it is putting the complex before the simple; and, although viscera may be had at the butcher-shops, we fail to see what is gained on the score of "messiness" by substituting them for "slugs or snails," or the simpler forms of life that can be procured anywhere. Prof. Huxley says that "plants do not make a mess—at least, they do not make an unpleasant mess," but the quality of the mess is not the important thing. The study of plants is resisted in schools, and, when attempted, is often abandoned, simply because of this circumstance; and, when the principle has been once conceded, as in the case of plants, the difficulty practically disappears in regard to animate things. If there is the slightest interest in the subject, there need be no trouble. Classes of children a dozen years old can go through Prof. Morse's admirable "First Book of Zoology," collecting numerous specimens of insects, shells, and creatures found in ponds and puddles, and, if his directions are followed, which may be easily done, there will actually be less litter and inconvenience than is usual with the study of plants. The "difficulty," in fact, is not real or intrinsic in the conditions of the case, but, as we have had occasion to notice again and again, it comes from the stupid ignorance and fussy meddlesomeness of parents, who bully the teachers at every deviation from the "horrid demnition grind" of book-lessons and recitations in the schools. The fact is, if we ever get the study of Nature into the schools, it can only be by breaking down the superstitions by which they are dominated; the deadly order, by which Nature is kept out; and by a larger recognition of individual aptitudes, and much freer opportunity for the observation and study of natural objects.

SOME QUESTIONS ANSWERED.

A PUBLIC appeal was made, through the *Tribune*, by Rev. Dr. Deems, to the editor of THE POPULAR SCIENCE MONTHLY, to make good certain statements contained in the criticism of Dr. Taylor's letter. Dr. Deems avows that his "questions are submitted for information," but we suspect he is not half

so ignorant as he pretends; as others, however, are also asking for explanations, we will consider his most important points.

We had remarked: "A theory is said to be demonstrated when it brings all the known facts into agreement, explains them, excludes all other interpretations, and is consistent with itself and all that is understood of the ways of Nature." Dr. Deems asks: "Did Prof. Huxley 'bring all the known facts into agreement?' Did he show that his theory was 'consistent with all that is understood of the ways of Nature?' Did he not tacitly admit that he was not able to show that his theory was 'in agreement' with what physical astronomy teaches us of the 'ways of Nature?'"

Prof. Huxley certainly made no such admission in any form or degree, and we are at a loss to see how his utterance or the report of it can be so construed. Possibly it is because he dismissed the subject somewhat curtly, which was interpreted into an unwillingness to face it, accompanied by the further inference that he was unable to do so. But it is to be remembered that the question was thrust upon him by editorials in leading newspapers and by private communications, and was not embraced in the plan of his argument, to which he had not half time enough to do justice. He was, therefore, compelled to be brief; but the case was squarely met. It had been objected that evolution cannot be true because physical astronomy proves that there has not been time enough since the cooling of the earth for the slow processes of life-unfolding to have taken place. To this Prof. Huxley replied, first, that he had already considered the subject in an address before the Geological Society of which he was president, and had showed that the "teachings of physical astronomy" as against geological time are not sound; and he, moreover, knew that this address was accessible to all interested, as it had been circulated by thousands in this country in his volume of "Lay Sermons." Is this to be construed into inability to maintain his theory against the objections raised in the name of physical astronomy?

Secondly, Prof. Huxley replied that, granting the validity of the case made out by the "physical astronomers" (which, of course, he did not grant), even then the biologist has little reason to trouble himself about the result. His proof of evolution comes from another source, and demonstrates to him that there must assuredly have been time enough for its occurrence. It has been customary to affirm that the evolution of life has proceeded at a very slow rate, and required vast periods of time; but what is the basis of the assumption? It is that the series of living forms is distributed through extensive deposits of stratified rocks which the geologist says it has taken vast periods of time to make, and, as the course of life-changes has been coeval with the course of strata-deposition, if the geologist is right, evolution must have been slow. But, if the geologist revises his data either way, the biologist will simply accept the result, and occupy the time. He only says: "There, in the vast succession of rocks, is our proof of evolution as a matter of fact; the geologist and the physicist may settle the question of time between them, and inform us, if they can, how long it has taken." And what is there here of tacit concession that his case was weak as against the "teachings of physical astronomy?"

Let us now briefly examine that case, and see how much occasion for anxiety it gives to the adherents of the doctrine of evolution. "The teachings of physical astronomy" here referred to mean the mathematical and physical speculations of Sir William Thomson in regard to the rate of cooling of the sun and of the earth, the retardation of the earth's rotation by the drag and

friction of the tides, the influence of melting polar ice, etc., speculations that have by no means taken their place among the established principles of physical astronomy. But Sir William Thomson concludes that a limit is to be put to the time during which life can have existed upon the earth. Yet it must not be supposed from this that his chronology at all approximates to that of Archbishop Usher. He assumes, and draws his arguments from, the nebular hypothesis, and, instead of starving the geologists in their allowance of time, it must be confessed that he deals with them very liberally. He says he believes that "the existing state of things on the earth, life on the earth—all geological history showing continuity of life—must be limited within some such period of time as one hundred million years." "Some such period of time!" This is sufficiently vague, and raises the query, "Does it mean that the time may have been two, three, or four hundred million years?" Prof. Thomson himself puts this interpretation upon it when he says elsewhere of the high surface-temperature which made life impossible: "We must still admit some limit, such as fifty million years, one hundred million years, or two or three hundred million years ago. Beyond that we cannot go." And, again, he expresses the opinion that the sun has not really illuminated the earth for a period of five hundred million years.

But are the geologists so very badly cramped by these limitations—even assuming them to be established? The total thickness of stratified rocks containing traces of life may be taken, on the best geological authority, as one hundred thousand feet, or nearly twenty miles. The deposit of one hundred thousand feet of stratified rock, in one hundred million years, implies that the deposit has taken place at the rate of about one-eighty-third ($\frac{1}{83}$) of an inch per year. If the "some such period" was double that time, then a hundred and sixty years would be allowed for the accumulation of an inch of sedementary rock; or, if three hundred million years are taken, the rate of stratified growth would be one-two-hundred-and-forty-ninth ($\frac{1}{249}$) of an inch annually. This is a very moderate pace, and certainly affords little ground of complaint on the part of the biologist that he is pinched for time by the geologist and physicist. Prof. Huxley, therefore, had not the slightest reason for admitting that his theory was not "in agreement" with what physical astronomy teaches us of the "ways of Nature."

Continuing the same line of thought, Dr. Deems quotes our remark that "it is a demonstrated fact that life has existed on the globe through periods so vast as to be incalculable," and asks: "Where, when, and how, was this ever 'demonstrated?' Has it not been shown that within a period not 'incalculable' life could not have existed on this globe?" We certainly did not mean that the resources of arithmetic are insufficient to express the time during which life has existed upon earth, but we did mean that the periods are so vast and obscure as not to be brought within definite estimate or "calculation." And of this the whole science of geology affords the demonstration. If the rocks have been formed in succession, as geology has proved, and twenty miles of strata have been piled over the earliest-appearing forms of life, then the time since living creatures came has been indefinitely vast, and that the periods are not amenable to anything like "calculation" or trustworthy estimate is shown by the way the subject is dealt with in our most authoritative geological works. Where uncertainty enters largely, positive calculation is excluded, and accordingly we find that when the ablest geologists approach this subject they either abstain from any attempt at calculation, or they refuse to deal with it, in terms of years and talk of eras, epochs, and cycles. Prof. Dana speaks

"of the relative lengths of the ages and periods, or their time-ratios," and says "future discovery will probably enable the geologist to determine these ratios with far greater certainty and precision. Although geology has no means of substituting positive lengths of time in place of such ratios, it affords facts sufficient to prove the general proposition that *Time is long.*" This "proof" we hold as demonstration; and the substitution of "relative lengths of ages and periods" for "positive lengths of time" certainly justifies the use of the term "incalculable" as applied to them.

We had said that "it is a demonstrated truth of Nature that matter is indestructible," and Dr. Deems asks: "When, where, and how, was this ever 'demonstrated?' Even if it be true that matter is indestructible, can it be demonstrated? Dare any but an infinite intellect make such an assertion?" It was a theory held for thousands of years that, in the workings of Nature, matter is constantly created and destroyed—comes out of nothing and goes back to nothing. Modern science brought this theory to the test of experiment, and showed that it was erroneous. No facts were found to sustain it, but, on the contrary, all the facts prove the truth of the opposite theory, that the changes of matter are changes of form, and that matter itself is indestructible. A theory is demonstrated when all the facts verify it. Every experiment and observation in the whole body of science, physical and chemical; every fact, induction, and deduction, reached by the human mind, confirms the truth of the indestructibility of matter, and there is no shadow of evidence against it. What is this but a demonstration? And, if the proposition is sustained by this high degree of proof, we fail to see what there is of "daring" in giving it a label that expresses the fact.

There remains another important point suggested by a question of Dr. Deems, which, for want of space, we put over to next month.

PROFESSOR MORSE'S LECTURES.

Prof. Morse has been quietly delivering a course of four lectures, in the large hall of the Cooper Institute in this city, on "Evolution." We say *quietly*, because there has not been much said about them by the press, as they have been given in the admirable series of free Saturday evening lectures that run through the season, and have become matters of course with the lecture-going public. Yet these lectures of Morse's might well have attracted the prominent attention of our newspapers, as they were unequaled in the skillful presentation of biological facts and principles commonly dry and forbidding, so as to be perfectly understood and intensely relished by large audiences of non-scientific people. Prof. Morse has remarkable gifts as a lecturer, and in the field of science is without a peer on the American platform. In the first place, he knows his subject thoroughly, and is charged to overflowing with its latest and freshest facts and illustrations. In the second place, he has a faculty of rapid and accurate delineation of the forms and structures of life that he is dealing with, that is unique and unapproachable by any other man that we ever saw work with the blackboard. He chalks as fast as he talks, and while he talks, and without spoiling his talking; and by his marvelous creations he holds his auditors as closely through their eyes as their ears. His manner as a speaker is, moreover, free, colloquial, spirited, and impressive, and his utterances vigorous, pointed, and racy. These arts are, however, all subordinate to the solid work of instruction. The last lecture of his course, although dealing apparently with technical and formidable scientific facts concerning the relations of

organized creatures, living and extinct, was yet nothing less than a delightful entertainment. His vast audience of three thousand people were held spell-bound and so closely occupied with the interest of the discussion that the attempt at cheering was repressed as an interruption. Something, however, was due in this remarkable effect to the interest of the theme, and the rapid liberalization of public opinion that has latterly taken place; for fifteen years ago it would neither have been possible to get such a multitude together to listen to the uncompromising defense of evolutionary doctrines, nor could Prof. Morse have kept such a crowd in control even if they could have been got together.

BAIN ON EDUCATION.

The readers of the Monthly will hardly need any reminder as to the importance of carefully perusing the first article in our present number, concluded from last month, on "Education as a Science." Every art, when science comes to be applied to it, undergoes something like a revolution, as the principles which control it are gradually working out into such clearness that they can be followed in practice. And however important this fact may be in relation to the industrial arts, it becomes of infinitely greater moment when the object to be attained is the cultivation of the human mind. It is difficult to exaggerate the benefits which must follow the establishment of scientific principles for regulating the work of education, and every valuable contribution to this end is entitled to the most serious and sympathetic consideration.

Hitherto the dictators of educational method have been metaphysicians. Having taken possession of the province of mind, they have claimed to be law-givers in all that pertains to its management. But their method is vicious and misleading, from its incompleteness and want of a secure scientific basis. It has neglected the corporeal side of human nature. As mind is never manifested except by and through a material substratum, no analysis of it, no statement of its modes and conditions of working, can be scientifically grounded, or true to Nature, or full and trustworthy in its elements, that does not take into constant and essential account the organic concomitants of intellect and feeling, or the bodily organism. By doing this, mental science has not only been widened and deepened, but placed upon a positive foundation. Prof. Bain is a pioneer, and an eminent authority, in this great reform of mental philosophy. His principal works upon the human mind, "The Senses and the Intellect," and "The Emotions and the Will," are comprehensive expositions of mental science from this point of view, and have thoroughly prepared their author for treating the applications of scientific psychology to the practical business of culture. Indeed, no better vindication of this method of treating the subject of mind can be furnished than that which the reader will gather from his last essay on the conditions of mental acquisition in the paper herewith published. The vagueness of metaphysics here disappears, and the various forms of mental effort are graded, not with reference to abstract considerations, but with reference to the variable vigor and unequal plastic power of the corporeal system. The most important questions of practical education can only be resolved from this point of view, and from this point of view they are capable of being resolved in a way to command the confidence of teachers, and guide the operations of the school-room. Prof. Bain is expected to pursue the subject in future into the details of educational practice, and the readers of the Monthly will probably hear from him again before very long.

LITERARY NOTICES.

Fragments of Science: A Series of Detached Essays, Addresses, and Reviews. By John Tyndall, F. R. S. Fifth edition. New York: D. Appleton & Co. Pp. 625. Price, $2.50.

Prof. Tyndall's position in the world of thought, at the present time, is one of very marked individuality, and there go several strong factors into the composition of that wide and powerful influence as a thinker which he has exerted upon the mind of the period. In the first place, the age is scientific to so great a degree that all human interests are more disturbed by this agency than ever before. Prof. Tyndall's scientific acquirements and training are therefore in harmony with the great intellectual movement of which he has become a leader and representative. His chosen field of labor, moreover, that of physics, is the one which people generally are best prepared to appreciate, while his ingenuity and fertility in devising new and striking experiments for the illustration of facts, and the proof of principles, always compel attention to what he has to offer. Again, his consummate mastery of the arts of exposition, the clearness and beauty of his statements, and the high literary finish of all his work, give him the command of cultivated minds wherever English is read. Equally important, also, in any estimate of Prof. Tyndall's power, is that fearlessness of spirit, and unflinching allegiance to what he considers the truth, that give boldness to his utterances, and carry him to the front of the conflict, in which science struggles with the forces of ignorance, prejudice, and superstition. These elements, of course, are not equally combined in all his productions. In his scientific memoirs we have only the record of laborious and painstaking researches, but they are always elegantly written. In his volumes upon "Heat" and "Sound" we are chiefly struck by the lucid and methodical exposition, interspersed with poetic touches and expressions of fine feeling, awakened by the study of Nature's deeper harmonies, and which are a constant source of pleasure to the student. But it is in his various miscellaneous papers, some of them didactic, some controversial, and others devoted to the development of advanced opinions in which he is deeply interested, and all of them with a scientific substratum, and exhibiting the best excellences of his eloquent style, that we shall find the chief secret of the hold he has obtained upon all classes of readers. These papers were collected, a few years ago, in a volume entitled "Fragments of Science," which proved one of the most popular of his works. It passed through four editions, and the fifth now appears, greatly enlarged by recently-published articles, and containing one hundred and ninety-three pages of matter not found in the former American edition. Prof. Tyndall has rearranged the work, grouping together the more scientific articles in Part I., and the controversial discussions in Part II., to which there is a special and able introduction. All the articles have been carefully revised, with a view to making them, in the highest degree, clear and accurate. Commendation of this work is superfluous, but it is one of the volumes that wide-awake readers cannot well do without, and which is always ready to furnish instruction and entertainment for an odd hour.

Tollhausen's Technological Dictionary. Part I., French-German-English; Part II., English-German-French; Part III., German-English-French. New York: Holt & Co. Price, $3 50 per vol.

The compilers of general dictionaries of two or more languages have hitherto given but little thought to secure either fullness or accuracy in their vocabularies of technical terms, especially those employed in the useful arts. Such terms having no place in literature proper, and the existing dictionaries being designed mainly as keys to the literature of the various languages, the defect of which we speak becomes, under the circumstances, venial. But we are from day to day coming into closer industrial relations with the outer world, and the need of such a work as that before us has long been felt. The author of this work has spared no pains to make his dictionary complete and accurate, and he is to be congratulated upon the success with which he has performed his very difficult task. The first part of the work (French-German-English) embraces some 65,000 technical terms and

phrases, the second part (English-German-French) about 76,000, and the third (German-English-French) over 90,000. As was inevitable in a work involving so much research, errors are not wanting, and a multitude of technical terms have been omitted. Nevertheless, the author has rendered an inestimable service to the world of letters in the compilation of this dictionary; its defects will disappear under revision, as new editions are called for. In the mean time we are very well satisfied with the work as it stands, and can heartily commend it as a trustworthy guide to the synonomics of technical terms in the three foremost languages of modern industrial life.

Principia, or Basis of Social Science: Being a Survey of the Subject from the Moral and Theological, yet Liberal and Progressive Standpoint. By R. J. Wright. Philadelphia: J. B. Lippincott & Co. Pp. 524. Price, $3.50.

The activity of modern speculation on social subjects, while yet there are so few principles established for the guidance of thought, has led to the widest and wildest diversity in the treatment of this class of questions. This is perhaps the highest sphere of intellectual liberty, for in most other departments of thought there are restraints which come from more or less settled ideas. Thus in religion there are established creeds; in practical politics, constitutions, precedents, and the body of laws; in history, canons of interpretation; in science, facts, generalizations, and determined methods—all of which exert a regulative and controlling influence over the speculative tendency. But in the social field very little help comes from any such sources, and the fertile thinker is as free to spin theories and excogitate a philosophy as if he had been the first to start inquiry in this domain. That principles will at length be established to direct the course of investigation, we are not permitted to doubt; but, thus far, the chaos of social philosophy, and the conflict of social doctrines, are the most striking facts in regard to them.

Mr. Wright has made an earnest book, which is pervaded by an excellent spirit and noble aspirations, but his views are original and independent, and he has done his own thinking throughout, from his exposition of a radical and thorough-going socialism down to the punctuation of his volume, which he has carried out according to his own rules. So full a freedom of treatment ought to favor originality of suggestion and freshness of opinion, and the book will accordingly be found to contain many ingenious ideas, and to abound in hints and statements which will find a useful place in the future development of the subject. The author makes no large claims for his work, but simply submits it to the common-sense of his readers for what it may be worth in helping them to the study and understanding of social questions; and "hopes that, if the public cannot tolerate these writings as a work of science, they will, at any rate, tolerate them as a kind of sermon to politicians and statesmen."

Mr. Wright classes the elements or activities of man's social life in six categories or units, as follows: There is, first, the individual; second, the family; third, the social circle—by which he means groups of affiliated or closely-connected families; and, fourth, the precinct—by which he means to designate the neighborhood principle. The precinct is a fundamental idea in the social series which the author develops with special prominence. "Precincts," he says, "are neighborhoods organized into civil governments; they are territories *within* territories; they are *parts* of a tribe or nation, and are not self-existent. In other words, precincts are the organizations of the neighborhood principle in civil government. They might be compared with the 'States' of the American Union by calling them very small and *reformed* 'states.' The precinct is the fourth fundamental element or 'personality' of society as determined in our analytics." The precinct is distinguished from the corporation, and is the smallest political group, but in Mr. Wright's scheme it is endowed with many of the most important functions of government.

The fifth unit is the nation, which is political on the larger scale; and the sixth unit of society is mankind, or the human race, the aggregate of all nationalities. Under this classification the author discusses a wide range of questions—in fact,

everything that belongs to government, reform, philanthropy, education, social progress, communism, etc. The present volume is the first of a series to be carried out as the leisure or opportunity of the author may allow.

The Problem of Problems, and its Various Solutions; or, Atheism, Darwinism, and Theism. By Clark Braden, President of Abingdon College, Illinois. Cincinnati: Chace & Hall. Pp. 480.

In a note prefixed to this volume, and addressed to reviewers and critics, the author requests these parties to "carefully read the book before they review it." This is only fair, and we undertook to comply with the writer's wish, but failed to get through with it either carefully, hastily, or in any other way. For life is short at the best, and is rapidly shortening, while work multiplies, and but little time is left for reading. Moreover, President Braden's volume is very substantial, and contains a good deal of printed matter on a page, which increases alarmingly after the 342d. Beyond doubt, if the depth of the work is in proportion to its length, it must be valuable. Not having carefully read it, we shall not venture to review it, but we quite agree with the author as to the importance of the discussion; and, as in his title he has sandwiched Darwinism between Theism and Atheism, our readers will infer his point of view to be that of the theologian. The book is a theological onslaught upon the school of thinkers of which Mr. Darwin is now the most conspicuous representative. We gather from the introduction that the author formerly did vigorous service, and probably won his theological spurs, as a fighter of infidels in public debates and written discussions. He considers that this has afforded him a valuable "training" as a champion of religion against the new phase of scientific infidelity, and which enables him to deal very decisively with Darwin, Mill, Huxley, Spencer, Draper, Tyndall, and the like, whom he cuffs and mauls about, in his book, without the slightest mercy. The "Problem of Problems" is obviously a good deal such a work as "Modern Physical Fatalism," which we noticed last month, but is much longer.

Aërial Navigation. By the Late Charles Blatchfield Mansfield, M. A. Edited by his Brother, with a Preface by J. M. Ludlow. Macmillan & Co. Pp. 513. Price, $5.

The author of this book, who wrote also "Travels in Paraguay and Brazil," and a "Theory of Salts," is said by Mr. Ludlow, in his preface, to have been a man of great fertility and originality of mind. He says:

"Those who knew him intimately—a now fast-narrowing circle—recollect well how there would come upon him occasionally, after intervals of quiescence, a kind of divine *afflatus*, and for a time his mind would bring forth one device after the other in rapid succession, as those to whom the world restricts the name of poets multiply their works during periods of creative energy. The present volume is the fruit of one of these periods, and the words at the close of the author's preface, 'My object in writing it will be simply to deliver my brain of a burden which came upon it uninvited,' express, I believe, the strictest truth as to his mental experience. . . .

"If it be asked why, after the lapse of a full quarter of a century, an unfinished work by one who is no more on earth is presented to the public, the answer is—1. That the author himself wished to have so presented it when perfect, and that he was one of those whose wishes have a right to be carried out as far as may be practicable. 2. That although the fact that he never completed it might militate against its publication unfinished, yet it does not appear that any publication issued since his death has in any wise taken the place which this volume was meant to occupy. 3. That during the same interval events of high gravity in the world's history have shown that the question of aërial navigation may be one of life and death to a nation. For we have lived to see, what Charles Mansfield did not, France governed through balloons from besieged Paris, and a dictator, who refused to despair of his country, cross the air over the heads of hostile armies."

Mr. Mansfield believed in the practicability of aërial navigation, and that the problem will at length be solved, and the work is a close and searching inquiry into the principles upon which such solution must depend. It will, therefore, be important to the students of aërostation.

The following passage from that witty philosopher, Hans Christian Andersen, when treating of the "ugly duckling," serves as a motto for the volume: "'What next, I wonder?' said the hen. 'You have nothing to do, and so you sit brooding over

such fancies. Lay eggs or pur, and you'll forget them.'

"'But it is so delightful to swim on the water,' said the duck; 'so delightful when it dashes over one's head, and one dives down to the very bottom.'

"'Well, that must be a fine pleasure,' said the hen. 'You are crazy, I think: ask the cat, who is the cleverest man I know, if he would like to swim on the water, and perhaps to dive, to say nothing of myself. Ask our mistress, the old lady, and there is no one in the world cleverer than she is: do you think that she would like to swim on the water, and for the water to dash over her head?'

"'You don't understand me,' said the duck."

Twelve Idioms spoken in the Southwest of the United States: Pueblo and Apache Dialects, Tonto, Tonkawa, Digger, Utah. Vocabularies, published and commented upon by Prof. Albert S. Gatschet. Weimar, 1876. 8vo, pp. 150. (In the German language.) Westermann & Co.

In this volume a series of vocabularies and phraseology, collected by members of Lieutenant George M. Wheeler's survey-parties, were made the object of a comparative investigation by the author, a resident of New York City, who is already known to the scientific world by various treatises on Indian languages, and on European dialects found in the Alpine valleys. Oscar Loew, chemist of one of Lieutenant Wheeler's parties, collected the main portion of these vocabularies, adopting for them the alphabetical notation recommended by the Smithsonian Institution. To solve the long-standing problem of the primordial habitat of the Aztec tribe, which forms a portion of the far-stretching Nahua race of natives, the author has united all the linguistic information which can at the present time be derived from the study of the Pueblo languages, and has also illustrated the radical affinities of the other language-stocks, which form the object of the publication. In addition to this, the volume contains one of the most exhaustive enumerations of American language-stocks and dialects ever attempted from the genealogical standpoint, embracing North, Central, and South America, and gives a transparent synopsis of the plan of thought and the morphological processes observed in various idioms of the Western Hemisphere. From a separate chapter, the contents of which are novel to science, and of the highest linguistic interest, we become enabled to follow Indian thought and Indian combinatory powers to the very abysses and mysteries of primeval word-formation and word-composition.

A short appendix compares and analyzes numerous terms embodied in the large word-table on pages 97 to 117, and classifies the numeral adjectives according to the various systems of numeration in use all over the divers parts of the globe (binary, quinary, etc.). On the last pages two curious Southern rock-inscriptions are figured and their interpretation attempted.

The Land-Birds and Game-Birds of New England, with Descriptions of their Habits, and Notes. By H. D. Minot. Salem: Naturalists' Agency, 1876. Pp. 350. Price, $3.

This book is likely to attract the attention of ornithologists on account of both its good and bad qualities. It is restricted in its scope to New England, and intended chiefly to report what the author has himself observed in the neighborhood of Boston, but the biographies are extended by copious quotations. Mr. Minot seems to regard the subject from the standpoint of an oölogist, and makes the breeding habits of birds the most prominent feature of his history. The long introduction is especially addressed to egg-collectors or students, and contains minute information upon forming oölogical cabinets. This portion of the book should have been revised by the author, and cut down at least one-third. As to the long appendix, embracing keys by which to identify the eggs of the birds, and the birds themselves mentioned in the volume, it is practically useless; while the construction of the two indexes is foolish. This misfortune arises from the method of the book, which—its character and object considered—is altogether bad. The arrangement of his subject-matter, under various signs and paragraph-marks, is only an obstruction, and we are sure the really great value of the work, as a whole, would

be much more striking if this complicated, cross-reference catalogue arrangement had been dispensed with.

Although the information conveyed is local, the accounts of the habits of the birds contain many new and valuable facts, stated in a way to inspire confidence in the reader. Mr. Minot's style, though often somewhat crude, and showing marked defects, is pleasant and strong. He has paid particular attention to the notes and songs of birds, and describes their music felicitously. Evidently he has had a sharp eye upon them everywhere, and under all sorts of circumstances, for his delineations abound in minute touches, which show close observation.

The Andes and the Amazon; or, Across the Continent of South America. By James Orton, A. M. Third edition, revised and enlarged, containing Notes of a Second Journey across the Continent from Pará to Lima and Lake Titicaca. With two Maps and numerous Illustrations. New York: Harper & Brothers, 1876. Price, $3.

In popular interest and in general scientific value this volume by Prof. Orton will occupy a favorable position among the many excellent books of South American travel that have appeared since the great work of Darwin in 1835, and to whom the volume before us is fittingly dedicated.

The account of the first journey, made in 1867, was published soon after, and was favorably received. The route on that occasion was from Guayaquil to Pará, at the mouth of the Amazon, by way of Quito.

The second journey was made in 1873, and commenced where the first one terminated.

By aid of two excellent maps, the route of the traveler can be followed from Pará up the Amazon, thence through forests, and over horrible roads upon the eastern slope of the Andes, to the great plateau and city of Cajamárca, "the most beautiful plain in all the Andes." The city is 9,400 feet above the Pacific. In it are the remains of Atahuallpa's palace and other memorials of the struggles of the Peruvians with the Spaniards.

"Two days from Cajamárca, the party shouted for joy at the sight and sound of a locomotive," a sign that their hardships were over. The Andes of Peru are being traversed by roads grander than those of the Aztecs.

Having arrived at the Pacific coast, a half-hour's ride by rail took the travelers to the city of Lima. Arriving at Mollendo, a new village, "with the ocean on one side and a vast desert on the other," Prof. Orton took the train for Lake Titicaca, a distance of 325 miles. He was the first passenger over the newly-finished road to the lake from the Pacific. The route is over deserts and apparent solitudes, on which look down some of the snowy giants of the Andes 18,000 feet high. At 107 miles the train stopped at Arequipa, a city in a valley of green verdure; and, finally, at Puno, an Indian village, 12,547 feet above the ocean. Before reaching it the waters of Lake Titicaca were seen.

The highest point on the route was 14,660 feet, where snow lay on the hills, and where there was no sound of life. "So profound was the stillness that the buzzing of an insect would have been painful."

"I gazed," says the author, "rapt in thought, upon the lake, brimful of history. Its surface, at a height of 12,493 feet, lies level with the tops of lofty mountains, and it has an area of 2,500 square miles."

Everywhere around it are monuments of a civilization which has passed away.

Of the railroads of Peru, the Oroya, which was being built, will attain at its greatest elevation a height of 15,645 feet above the level of the sea.

The geology and natural history of the Amazon region and the Andes, their resources and inhabitants, make several chapters of great interest. Besides two maps, the volume contains 80 illustrations.

Science Lectures at South Kensington: 1. "Photography," by Captain Abney. 2. "Sound and Music," by Dr. Stone. 3. "Kinematic Models," by Prof. Kennedy. Manchester Science Lectures for the People: 1. "What the Earth is composed of," by Prof. Roscoe. Macmillan & Co.

These are all excellent addresses by able men, and as popular as the nature of the subjects will allow. They are illustrated, and on good paper, and the publishers furnish them at 20 cents apiece.

Practical Cookery and Dinner-giving. A Treatise containing Practical Instructions in Cooking; in the Combination and serving of Dishes; and in the Fashionable Modes of entertaining, at Breakfast, Lunch, and Dinner. Illustrated. By Mrs. Mary F. Henderson. Harper & Brothers. Pp. 376. Price, $1.50.

Notwithstanding the multitude of books, good, bad, and indifferent, that treat of cooking and eating in all their aspects, the subject is yet far enough from being exhausted—the plenitude of its literature serving chiefly to convince us of the importance of the subject. But there is evidently an awakening in the culinary world, and a growing sense that, although it may have rained cook-books for a century, the work of reforming the kitchen and dining-room, and bringing them into some rational method of management, remains still to be accomplished. The dissatisfaction with bad cooking and barbarous eating is steadily spreading, cooking-schools are multiplying, and many are asking anxiously what can be done to amend our imperfect and evil ways in the preparation and serving of food.

Mrs. Henderson has therefore chosen a fitting time to put forth the results of her study, observation, and experience, on these important matters, and her volume, we think, will be widely welcomed and appreciated, as an excellent contribution to the literature of domestic economy, at the present time. It is comprehensive and practical, and meets the general wants of families in a satisfactory way. It contains much information in regard to culinary implements, processes of cooking, and the methodical operations of the kitchen, which if made available will be certain in most cases to improve that branch of the domestic establishment. It is the merit of Mrs. Henderson's book that it is something more than a compilation; it has grown out of her own practical interest in kitchen-work, much observation and correspondence, and an enthusiasm for housekeeping which ought to be more frequent among ladies. She gives an excellent array of selected receipts, many tested by herself, and others by competent friends, while the choice seems to have been made with discrimination, such only being offered as have "stood the test of time and experience."

An important portion of Mrs. Henderson's book, and which will meet a want in many families, is the prominent attention she gives to the art of serving meals. She says, in her preface: "Care has been taken to show how it is possible with moderate means to keep a hospitable table, leaving each reader for herself to consider the manifold advantages of making home, so far as good living is concerned, comfortable and happy." Mrs. Henderson expatiates on "the fashionable modes of entertaining at breakfast, luncheon, and dinner," but insists that, in this case, fashion is not the equivalent of folly. There is a general impression that the genteel mode of doing the thing is expensive and extravagant. This would, of course, be so in many cases where ostentation is the object, but according to Mrs. Henderson it is not necessarily so. "Fortunately," she says, "the fashionable mode is the one calculated to give the least anxiety and trouble to a hostess." People will no doubt continue to dispense breakfasts, lunches, and dinners, on a scale proportioned to their means, but the author of this book aims to point out how a family can live well and in good style, and at the same time with reasonable economy. The book is written in a simple, direct, and common-sense manner, that leaves nothing wanting in the way of clearness.

A Course of Practical Instruction in Elementary Biology. By T. H. Huxley, LL. D., etc., assisted by H. N. Martin, B. A., etc. Macmillan & Co., 1876. Second edition, revised.

Prof. Huxley has made himself remarkable among the leading scientific lights of the day, quite as much by the ease and assiduity with which he has simplified and expounded to the unlearned the mysteries of natural history as by the mental acumen and power which have enabled him to discover so many of those mysteries. He is known better, perhaps, in England to-day as a teacher than as an investigator; hence it is not surprising that he has undertaken to sketch out and supervise the little book, costing only two dollars, of elementary biological lessons, which has been written by Prof. Martin, his former assistant and now Professor of Zoölogy at Hopkins University in Baltimore. It has grown out of Prof. Huxley's own experience as a teacher, and hence

is a thoroughly practical guide for progressive laboratory-practice, approaching the study through morphology and botany, which the professor considers the only safe road to a sound knowledge. "The study of living bodies," the author tells us, "is really our discipline, which is divided into zoölogy and botany simply as a matter of convenience, and the scientific zoölogist should no more be ignorant of the fundamental phenomena of vegetable life than the scientific botanist of those of animal existence."

The object of the book being to make it a laboratory-guide, a number of common and readily-obtainable plants and animals have been selected in such a manner as to exemplify the leading modifications of structure which are met with in the vegetable and animal worlds. A brief description of each is given; and the description is followed by such detailed instructions as will enable the student to know, of his own knowledge, the chief facts mentioned in the account of the animal or plant. "The terms used in biology will thus be represented by clear and definite images of the things to which they apply; a comprehensive and yet not vague conception of the phenomena of life will be obtained; and a firm foundation upon which to build up special knowledge will be laid." Beginning with yeast, gradual advance is made to successive studies of protococcus, proteus animalcule, colorless blood-corpuscles, bacteria, moulds, stoneworts, ferns, the bean-plant, the bell animalcule, fresh-water polyps (*hydra*, etc.), the fresh-water mussel, the crawfish and lobster, and lastly the frog. A sketch of the habitat and general characters, the development, mode of growth and microscopic structure, anatomy, modes of movement, etc., etc., of each is given, followed by a schedule of laboratory-work, directing the student, with the aid of excellent figures, to the recognition of all the parts of the animal or plant studied, not only in their shape and position, but in their relation to other parts, their functions and their development. The chief labor in drawing up these instructions has fallen upon Dr. Martin; but for the general plan used, and the descriptions of the several plants and animals, Prof. Huxley holds himself responsible. The result is a book of the greatest value for beginners in the study of biology; supplement it by Rolleston's "Forms of Animal Life," and we have a whole library. Students who wish to "know of their own knowledge" can certainly find no better guide than this.

Lectures on Some Recent Advances in Physical Science. With a Special Lecture on "Force." By G. P. Tait, M. A. Second edition, revised. Macmillan & Co. Pp. 363. Price, $2.50.

Of this new edition we can only repeat what we said at the appearance of the first, that it will be found an instructive discussion of modern dynamical problems, well worth the perusal of all who are interested in this class of questions. The pugnacious temper of the author, or rather perhaps the facility with which he gets into hot water with other scientific men, is illustrated by the preface to the new edition, which is chiefly devoted to his quarrel with the German physicist, Prof. Clausius. In his additional lecture on "Force" he discusses the different meanings that are given to the term, and the confusion that results. His conclusion is, that "there is probably no such *thing* as force at all! that it is in fact merely a convenient expression for a certain 'rate.'" We suspect that more work will have to be done here before the matter will be finally cleared up.

Essays in Literary Criticism. By Richard Holt Hutton. Philadelphia: Coates & Co. Pp. 355. Price, $1.50.

It is one of the great defects in literary criticism that a person who admires certain books or authors cannot detect their faults, and that he who is prejudiced against them is unable to see their excellences. Mr. Hutton is, in a remarkable degree, free from this deficiency, and points out failings in his favorite authors which even a hostile critic might not have observed. His great power is in being able to get at the fundamental thoughts of the men whom he criticises. He is apparently more concerned in expressing with careful minuteness all his ideas on a given subject than in elaborating them into an elegant style. The essays which make up this volume are on "Goethe," "Nathaniel Hawthorne," "Arthur Hugh Clough," "Wordsworth," "George Eliot," and "Matthew Arnold."

The Life-History of Our Planet. By William D. Gunning. Illustrated by Mary Gunning. Chicago: W. B. Keen, Cooke & Co. Pp. 368. Price, $2.

To the obvious criticism that so large a subject as "The Life-History of Our Planet" cannot very well be compressed within the limits of a handy volume like the present, it may be fairly replied that an outline of such a history, giving its leading features and more impressive aspects, is altogether a practicable thing. Prof. Gunning has shown this in the preparation of the volume before us, which certainly presents the leading historic aspects of terrestrial life in a manner that is highly instructive. The book is a successful attempt to popularize a great branch of science without sacrificing or cheapening it. Although the author deals with many new facts which are usually wrapped in an obscure terminology, he yet presents them in such a plain, familiar, direct, common-sense manner as to be understood by all readers who have the slightest interest in the subject. Well experienced in public teaching, he neither overshoots the average capacity nor wearies it by dwelling too long upon the minutiæ of his topics. He, moreover, gains much in compression of statement by giving prominent attention to the general views and truths of his subject, rather than to its interminable particulars. His mode of exposition is indicated in the following prefatory passage: "Facts do not enlarge the mind unless they are fertilized by principles. Our aim in the preparation of this volume has been to conduct the reader through methods to results. The leading types of life which have possessed the earth from age to age, he will find described and delineated. He will find the more significant types reconstructed, part by part, with so little of the phraseology of comparative anatomy that his mind, it is hoped, will traverse the methods and make them his own." The aim here proposed has been well attained, and, by treating his subject in the light of the great principles of unity, correlation, progressive unfolding, and interconnection with the course of physical Nature, the author has invested the great historical problem of the earth's past life with unusual interest and attractiveness.

We should like to quote copiously from "The Life-History of Our Planet," but have not room to do so. The following passage is representative, and illustrates the writer's clear and pointed way of picturing phenomena before the minds of his readers:

"In 1818 Traill dissected one of the higher apes, and found in the region of the thigh a muscle which he thought had no representative in man. He named it the *scansorius*, or 'climbing' muscle. Late dissections have shown Traill to have been in error. Its homologue in man is found to be the little muscle called *gluteus minimus*. What is the meaning of this little useless muscle in man, unless it is the atrophied descendant of a real scansorius? In that man-like ape, the orang, Dr. Barnard, of Cornell, has found a muscle whose homologue has never been found in man. In the orang it occurs as a vestige. It has almost faded out. It occurs in the lower apes and in the half-apes, but always as a vestige, having no functional value. It appears again in the opossum, but no longer as a vestige. Thus, a muscle which is obsolete in man, almost obsolete in the higher apes, less aborted in the lower apes, still less aborted in the half-apes, is found in the opossum with its functional value."

The first chapter of the book is devoted to what may be called the preliminary physics and geology of the subject. The second, third, and fourth, treat of the rise and evolution of organic types, and the fifth is devoted to the question of glaciers and the part they have played in the history of the earth's surface. This is an excellent chapter, and gives a very clear account of that most difficult matter for popular explanation—the relation of the precession of the equinoxes, and the secular variations of the earth's orbit to the glacial periods. The development of animals, the appearance upon earth of man, his antiquity and migrations, and the origin and derivation of races, occupy the remaining four chapters of the work, which may be regarded as a kind of preliminary text-book of philosophical biology. It is neatly and fully illustrated, and deserves to have a wide circulation.

The American Library Journal. (Monthly.) Managing Editor, Melvil Dewey. New York: F. Leypoldt. Yearly subscription, $5.

More than usual interest has been taken in the public libraries during the last year. The recent conference at Philadelphia, and the Report of the Educational Bureau at Washington, have now been supplemented by the *Library Journal*. Its plan is to cover the entire field of library and biblio-

graphical interests, to answer, by leading articles, communications, notes, etc., all the questions which come up in the experience of librarians, and to form "an inspiration that will keep them up to their profession."

The coöperative system ought to work with as much benefit in libraries as it does in other cases; and if, by mutual assistance, their condition can be improved, the good influence will extend to the people who use them. It was for the purpose of helping on in this good work that the *Library Journal* was undertaken. There is a large band of associate editors, representing the leading libraries of the country, who should be able to make this periodical valuable to all interested in the subject.

Report of the Exploring Expedition from Santa Fé to the Junction of the Grand and Green Rivers in 1859, under the Command of Captain J. N. Macomb; with Geological Report by Prof. J. S. Newberry. Washington: Government Printing-Office. Pp. 152.

The larger part of this work is occupied with Prof. Newberry's geological report. This was originally written and prepared for publication in 1860, but did not appear on account of the rebellion. Accompanying it is a map of the region, with eleven water-color sketches, showing the characteristic scenery, and eleven drawings, three of scenery and eight of fossils. The report concludes with descriptions of the cretaceous, carboniferous, and triassic fossils collected on the expedition.

Forest-Culture and Eucalyptus-Trees. By Ellwood Cooper. San Francisco: Cubery & Co. Pp. 238. Price, $1.50.

A lecture by the author on "Forest-Culture and Australian Gum-Trees" occupies the first part of this little book. To it are appended four essays by Frederick von Müller, of Austria, discussing various subjects relating to forest-culture, the desirableness of planting trees, etc. The cultivation of trees is a matter of considerable importance, and this work is intended to impress it upon the public attention.

The "Fifth Annual Catalogue of the Santa Barbara College" takes up the last thirty pages of the book.

Vaccination as a Preventive of Small-pox. By W. C. Chapman, M. D. Toledo: Brown & Faunce. Pp. 91.

There is found to be an inverse ratio between vaccination and small-pox, and the average amount of deaths from small-pox has been only two in a thousand in those countries where vaccination has been rendered compulsory. Its importance is now universally admitted, though it is not so generally acted upon, and for this reason any fresh reminders cannot fail to be beneficial. While advancing nothing absolutely new, Dr. Chapman presents the existing knowledge in a manner which affords a full understanding of the subject. After giving a history of its earliest application and development, he discusses the following questions: "Does vaccination protect the system from contagion of small-pox? Why does the protective power of vaccination become so impaired as to render revaccination advisable? What causes have prejudiced the public against the operation of vaccination? What measures should be instituted to enforce a due appreciation of the benefits of vaccination?"

Rules for a Printed Dictionary Catalogue. By Charles A. Cutter, Librarian of the Boston Athenæum. Washington: Government Printing-Office. Pp. 89.

This pamphlet forms the second part of the United States Government report on the public libraries. In many of our smaller cities and towns the value of the libraries is greatly impaired, since there is no direct way of discovering their contents, or of being able to find a book on a given subject. As the libraries enlarge and outgrow their catalogues, these difficulties increase. Mr. Cutter goes into the minutest details of classification in this essay, laying down 203 rules which he expands and illustrates. The work is, perhaps, a little too thorough to be altogether practical in the hands of many librarians. If the directions were not quite so numerous, and some of the details had been suppressed, it might have been more effective. A librarian will, however, be better able to utilize the books under his charge if he make himself familiar with the rules given by Mr. Cutter.

The Popular Health Almanac, for 1877. Edited by Frederick Hoffmann. New York: E. Steiger. Pp. 40. Price, 10 cents.

This is a valuable and most useful compilation of applied health-knowledge, such as should be found in every family. The first number was issued last year, and was so well appreciated that it is followed by another this year, and we hope the series will be continued. One of its most important features is to expose the traffic in patent medicines, and, to show their fraud and worthlessness, the chemical composition of many popular nostrums is given. We fully agree with the following estimate of this almanac, given by Dr. Elisha Harris: "Accept my thanks and very hearty congratulations for the admirable little manual which you have justly entitled 'Popular Health Almanac.' It certainly is the most acceptable and well-arranged compilation for public instruction on sanitary matters I ever saw; indeed, it is far more and better than a compilation, so happily has Dr. Hoffmann studied and crystallized the limits and substance of sanitary knowledge in the modest and beautiful little Health Mentor which, in all particulars, has been so wonderfully well designed and executed that thousands of families will sincerely thank its editor and publisher."

The First Fonakigrafik Teacher: A Guide to a Practical Acquaintance with the Literary Style of the Art of Phonachygraphy. An Improved Substitute for Long-Hand Script, etc., etc. Amherst, Mass., U. S. A.: John Brown Smith, Author and Publisher. Pp. 24. Price, 25 cents.

For such a humble little print as this the pretensions are very lofty, as it aims to make a revolution in the future modes of printing and writing. Following out the idea that "to save time is to lengthen life," the author remarks: "The saving of time in acquiring an education would be almost one-half if fonakigrafi (?) was exclusively used for both print and script, thus doing away with the absurdity of having half a dozen different alphabets for print and script as in use at present." Mr. Smith will, however, probably have to rack his brain again before he can invent a system that will completely set aside Pitman and his imitators or improvers. Undoubtedly, improvements will be made in the art of short-hand writing, but what direction they will take is not determined by this tract.

Matter and Force: A Course of Lectures on Physics. By J. K. Macomber. Ames, Iowa: Agricultural Steam-print. Pp. 95.

During the past few years Prof. Macomber has delivered the contents of this book, as a series of nine lectures, to his classes in Natural Philosophy. They are adapted to persons who have completed the elementary study of physics, and include the more recent views respecting matter and force. He treats, among other subjects, of "Potential Energy," and the "Correlation of Vital and Physical Forces," and gives the modern speculations in regard to the "Sun as a Centre of Force," with its relation to the existence of the solar system.

The Surface-Drainage of the Metropolitan District. By C. W. Folsom, C. E., of Cambridge. Boston: Wright & Potter, State Printers.

Mr. Folsom discussed this subject in the "Seventh Report of the Massachusetts State Board of Health," but its importance has warranted its separate publication. He does not attempt to treat surface-drainage exhaustively, but rather suggests its necessity, and the diseases to which its neglect gives rise, pointing out the particular districts in the neighborhood of Boston which are in greatest need of treatment.

The Essential Piety of Modern Science. A Sermon. By John W. Chadwick, Minister of the Second Unitarian Society in Brooklyn. For sale by Charles P. Somerby, 139 Eighth Street, N. Y.

Mr. Chadwick read this sermon or address before the National Conference of Unitarian and other Christian Churches, held at Saratoga in September. He shows a decided liking for modern scientific tendencies, and believes that there is that in scientific thought which directly fosters all those sentiments which are the life-blood of religion.

PUBLICATIONS RECEIVED.

Applications of Physical Forces. By Amédée Guillemin. Edited by J. N. Lockyer. New York: Macmillan. Pp. 770; with colored Plates and Illustrations. Price, $12.50.

Notes on Life Insurance. By Gustavus W. Smith. New York: Van Nostrand. Pp. 204. Price, $2.

Report of the Commissioner of Education. Washington: Government Printing-Office. Pp. 1,189.

National Quarterly Review. New York, 658 Broadway. Pp. 192. $5 a year.

European Surveys. By Major C. B. Comstock, of the Engineers. Washington: Government Printing-Office. Pp. 101.

Transactions of the Asiatic Society of Japan (1876). Yokohama: *Japan Mail* office. Pp. 178.

Celestial Dynamics. By J. W. Hanna. The author, Mount Vernon, Iowa. Pp. 32. Price, 35 cents.

National History of Illinois. Bulletin No. 1. With Plates. Bloomington: Pantograph Printing-House. Pp. 76.

Survey of the Northern and Northwestern Lakes. Major C. B. Comstock in charge. With Plates. Washington: Government Printing-Office. Pp. 84.

Catalogue of Swarthmore College, Pennsylvania. Pp. 55.

Effects of Alcoholic Poison. By J. H. Kellogg, M. D. Battle Creek, Michigan: *Health Reformer* print. Pp. 125.

The Mathematician. Royal Cooper, editor. Vol. I., No. 1. Pp. 16. Washington: *National Republican* print. $1.50 a year.

Giant Birds of New Zealand. By J. C. Russell. From *American Naturalist.* Pp. 11.

Biographical Notice of A. R. Marvine. By J. W. Powell. From the Bulletin of the Washington Philosophical Society. Pp. 8.

American Annals of the Deaf and Dumb. E. A. Fay, editor. Vol. XXII., No. 1. Pp. 64. Washington: Gibson Brothers print.

Climato-therapy of Consumption. By Dr. S. E. Chaillé. From the *New Orleans Medical and Surgical Journal.* Pp. 12.

Corundum. By C. W. Jenks. Boston: J. Wilson & Son, printers. Pp. 17.

Ueber die Darstellung und Eigenschaften des Trijodresorcins. Von Arthur Michael und Thomas H. Norton. Berlin: F. Dümmler. Pp. 2.

Intimidation and the Number of White and Colored Voters in Louisiana. By S. E. Chaillé, M. D. New Orleans *Picayune* print. Pp. 36.

POPULAR MISCELLANY.

Antarctic Icebergs. — Sir C. Wyville Thomson, in a lecture reported in *Nature* for November 30th and December 7th, presents facts of interest obtained during the cruise of the Challenger, concerning the antarctic regions visited.

The expedition met with its first ice five days' sail southward of the desolate, rocky group known as the Heard Islands. In a short time the ship was in the midst of bergs of exquisite beauty of both form and color.

The most southerly point reached was latitude 66° 40′ south, longitude 78° 22′ east, when they were exactly 1,400 miles from the south pole. The icebergs, some of them of immense size, were tabular in form, "the surface being level, and parallel with the surface of the sea . . . a cliff, on an average 200 feet high, bounding the berg. The cliffs were marked with delicately pale blue lines a foot apart near the top, closer together near the bottom; the intervening bands were white, probably from containing some air. . . . The stratifications of the bergs being originally horizontal, they were believed to be blocks riven from the edge of the great antarctic ice-sheet."

A further conclusion was that the stratification was due to successive accumulations of snow upon a nearly level surface. There was no evidence that the ice had passed over uneven surfaces, nor was there upon the bergs any trace of *débris*, such as might fall from elevated cliffs. The snow

upon the surface of the bergs was of dazzling whiteness, but, in places, faint discolorations, due not to earthy matter, but to the presence of birds, were observed. Prof. Thomson concludes that the ice from which the bergs were broken was found upon low, level land that was surrounded by shallow water.

Although no *débris* were seen upon the bergs, it is quite certain that large quantities of them were held in their under portions, whence they dropped into the sea, as such deposits were continually brought up by the dredge.

Prof. Thomson suggests that the increase of glaciers in thickness may be limited by melting at their under surface from pressure of the mass. A column of ice, 1,400 feet high, he estimates to lie upon the ground with a pressure of nearly a quarter of a ton to each square inch of surface, nor does he find reason to doubt that the temperature of the earth's surface beneath the glacier is about 32°. He cites the fact that from beneath glaciers in Greenland muddy streams are continually discharged. It is possible, therefore, that the antarctic glaciers, covering vast level tracts, are prevented from accumulating to a thickness much exceeding 1,400 feet, by waste in the bottom portions, where constant melting and regelation are going on.

On the chart of the American explorer, Lieutenant Wilkes, a position is given for what he called Termination Land. On closely approaching the spot, no land was found, and Prof. Thomson was "forced to the conclusion that Lieutenant Wilkes was in error."

The interesting fact was revealed by soundings that a layer of water 300 fathoms below the surface was warmer by several degrees than water at the surface, and it was ascertained that the heat increased northward. Hence it was concluded that the source of the warm water was northward, and that it may have been deflected by the southward projection of continental lands, turning southward currents which have their origin in the "great drift-current which sweeps round the globe."

Animals and Steam-Engines.—A writer in *Dingler's Polytechnisches Journal*, in noting the behavior of different animals toward the steam-engine, remarks upon the dexterity with which dogs run about among the wheels of a departing railway-train without suffering the least injury, whereas a host of railway workmen annually lose their lives. On the other hand, the ox, a proverbially stupid animal, continues standing composedly on the rails, having no idea of the danger which threatens him, and is run over. Many kinds of birds seem to have a peculiar delight in the steam-engine. It has often happened that larks have built their nests and reared their young under the switches of a much-traveled railway. In engine-houses the swallow is a frequent guest. In a certain mill, where a noisy, three hundred horse-power engine works night and day, two pairs of swallows have built their nests for years, and rear their young there regularly. A case of almost incredible trustfulness on the part of swallows occurred in the early part of last year, when a pair of these birds built in the paddle-box of a steamer, and regularly made the journeys from Pesth to Semlin. The author concludes with this caustic remark: "I have never yet found any animal at home in the boiler-house. Even the dog steers clear of boilers. It is almost as if the lower animals knew what an amount of stupidity and folly appears in our construction of boilers."

Prof. Dana on Cephalization.—The fifth of Prof. Dana's interesting papers on "Cephalization" is published in the *American Journal of Science and Arts* for October. The author's thesis here is that cephalization is a fundamental principle in the development of the system of animal life. As the animal grade rises, there is a compacting of structure in both the fore and hinder parts of the body. Of mammals the lowest forms are those having their locomotive functions in the posterior parts of the body, while in the higher forms the forces or force-organs are more and more forward in the structure. There are large size and strength behind in low forms, but a compacting of these and a better head in the higher.

The head becomes more and more the centre of nervous energy or force as development goes on, and this is to be seen in the specific forms of Nature. "Here form,"

says the author, "is with some limitations an expression of force."

Cephalization is shown both in embryonic development and in the progress of life in geological history. The law is further illustrated by the discoveries of Prof. Marsh, from which it appears that the brains of the great mammals of the early Tertiary were very much smaller than those of allied species of recent time. Thus the brain of the dinoceras, of the Eocene, was not more than one-eighth the size of that of the modern rhinoceros, showing an immense development of the brain, while the bulk of the animals has decreased. We have also a development of those features of both form and capacity which are characteristic of brain-power.

The increase of the brain and nervous system may arise, the author suggests, from the fact that this part of the structure comes in contact with outside and inside Nature, and is the means by which the animal has communication with the outer and inner world, and with its own inner workings and appetites. This constant and energetic use of the brain may have given to it its wonderful growth and strength since Eocene times.

But brain-progress could not have taken place without structural progress, and structural changes have been determined by it. Brain-force reacts upon and modifies both form and structure.

It is not claimed by the author that the theory of cephalization accounts for all the types of structure found in the animal world, but only that whatever these types may have been in course of development they were in general subordination to the principle of cephalization. "The origin of the grander types of structure," writes Prof. Dana, "must be connected with the profoundest of molecular laws; and how connected man may never know. These views may hold, whatever be the true method of evolution. The method by repeated creations should be subordinated, as much as any other, to molecular law and all laws of growth; for molecular law is the profoundest expression of the Divine will. But the present state of science favors the view of progress through the derivation of species from species, with few occasions for Divine intervention. If, then, there has been derivation of species from species, we may believe that all actual struggles and rivalries among animals leading to 'survival of the fittest' must tend, as in man, to progress in cephalization and dependent structural changes."

On the Origin of Prairies.—Having shown, in an article which we noticed in the December number of the Monthly, the untenableness of the current hypotheses with regard to the origin of prairies, Prof. J. D. Whitney now presents, in the *American Naturalist*, a theory of his own. He finds, as the result of a great number of observations made over all the prairie States, that almost without exception absence of forests is connected with extreme fineness of soil, and that this fine material usually occurs in heavy deposits. "No person," he remarks, "can have traveled through Southern Wisconsin, Illinois, Iowa, or Missouri, without having had everywhere occasion to observe that the prairie-soil is exceedingly fine and deep; there are whole counties in Iowa in which not a single pebble can be found." The distribution of the timbered and prairie tracts in Wisconsin affords a good test of the correctness of the author's hypothesis. In the northern part of the State is a region of dense forest, though this is not a region of large precipitation. It is, however, heavily covered with coarse detrital materials, plentifully distributed from the headquarters of the drift on Lake Superior. The rocks underlying the drift-deposits are crystalline, belonging to the Azoic series, and the surface is rough and broken, being intersected with low ridges and knobs of granite and trap. South of this is a large area, occupying the central portion of the State, and extending as far as the Wisconsin River, almost exclusively occupied by a very pure siliceous sandstone, which is wrapped about the Azoic region, extending in a northeasterly direction to the Menomonee River, and northwest to the falls of the St. Croix. This great sandstone-covered area is the pine-district of the State, while south of the Wisconsin is the region of oak-openings and prairies. When we reach these treeless tracts we have got entirely beyond the drift-covered area, and are upon a soil made up of the insoluble residuum left from

the disintegration of several feet in thickness of limestone and dolomite, which have been dissolved out and carried away by the rain.

Albertite.—This substance, now largely consumed as an enricher of illuminating gas, is thus described in a recent number of the *Iron Age:*

"A very curious mineral known as albertite is found in New Brunswick. It occurs in connection with calcareo-bituminous shales, and has been by some regarded as true coal, by others as a variety of jet, and by others again as more nearly related to asphaltum. The true nature of the mineral was made the basis of a lawsuit in Scotland a few years ago, in which the amount involved was something more than a million pounds sterling, as the decision settled the question of the liability to pay a royalty. It resembles asphaltum very closely, being very black, brittle, and lustrous, and, like asphaltum, is destitute of structure, but differs from it in fusibility and in its relation to various solvents. It differs from true coal in being of one quality throughout, in containing no traces of vegetable tissues, and in its mode of occurrence as a vein and not as a bed. The vein occupies an irregular and nearly vertical fissure, and varies from one inch to 17 feet in thickness. It has been mined to the depth of 1,162 feet. The accompanying shales are abundantly filled with the remains of fossil fishes, and it is not improbable that from these, in part at least, the mineral was derived, existing at first in a fluid or semi-fluid state. Vegetable remains are almost entirely wanting in the shales. During twelve years since the discovery there have been shipped 154,800 tons of albertite, chiefly to the United States, where it has been used for the manufacture of oil, and for the admixture with bituminous coal in the manufacture of illuminating gas. It is admirably adapted for either of these purposes, yielding 100 gallons of crude oil, or 14,500 cubic feet of gas of superior illuminating power per ton."

Singular Feeding Habits of Wood-Ants.—Mr. McCook, of the Academy of Natural Sciences of Philadelphia, has published in the "Proceedings" of that body some highly-interesting observations on the habits of *Formica rufa*, from which it appears that these ants have in their separate communities regular provision made whereby the workers are fed without having to quit the scene of their labors. The foragers of a community, as they come down the tree-paths, their abdomens swollen with honey-dew—in which condition they are called by the author *repletes*—are arrested near the foot by workers from the hill seeking food. The *replete* rears upon her hind-legs, and places her mouth to the mouth of the hungry worker, or "pensioner," as the author calls him, who assumes the same posture. Often two, sometimes three pensioners are thus fed at once by one *replete*. The latter commonly yields the honey-dew complacently, but sometimes she is seized and arrested by the pensioner, occasionally with great vigor. The author described a number of experiments leading to the conclusion that there was complete amity between the ants of a district embracing some 1,600 hills and countless millions of creatures. Insects from hills widely separated always fraternized completely when transferred. It was found, however, that ants immersed in water, when replaced upon the hills, are invariably attacked as enemies; the assailants being immersed were themselves in turn assaulted. Experiments indicate that the bath temporarily destroys the peculiar odor or other property by which the insects recognize their fellows.

How Meteorites were regarded in Olden Times.—There was a noteworthy fall of meteorites in Berkshire, England, in the year 1628, and devout persons with one accord seem to have looked on the phenomenon as a special act of Divine Providence. The meteorites are "the arrows of God's indignation," and he is entreated "to shoote them some other way, upon the bosomes of those that would confound his Gospell." One Mistress Green had the courage to order one of these heaven-sent "thunder-stones" to be dug out of the ground, and a chronicler of the time gives a description of it. The chronicler himself had little sympathy with the curiosity of Mrs. Green, for he warns his readers against being "so daring as to pry into the closet of God's determinations. His workes are full of wonders, and *not to be examined*." A letter written by an eye-witness of this fall of meteorites well illustrates the devout credulity of the time. It opens with the following passage: "The cause of my writing to you at this time is by reason of an accident that the Lord sent among us. I have heard of the Lord by the hearing of the ear, as the prophet speaketh, but now mine eyes hath seen him. You

will marvel that I write thus, for no man hath seen God at any time, yet in his works we see him daily, *but now after a more special manner*." Then, after giving a clear account of the whole occurrence, the writer concludes with an exhortation to unbelievers: "Now let the atheist stand amazed at this work of the Lord." In certain districts of Berkshire there is still a tradition of the fall of these meteorites, and old people speak of it as such an event as to have created a belief at the time that "the world was coming to an end."

Education in the Public Schools of Massachusetts.—Mr. Wendell Phillips recently delivered an address on the subject of education, in which occurred the following remarks upon the value of the intellectual training a girl receives in the public schools of Massachusetts: "The public schools teach her arithmetic, philosophy, trigonometry, geometry, music, botany, and history, and all that class of knowledge. Seven out of ten of them, remember, are to earn their bread by the labor of their hands. Well, at fifteen, we give that child back to her parents utterly unfitted for any kind of work that is worth a morsel of bread. If the pupil could only read the ordinary newspaper to three auditors it would be something, but this the scholar so educated, so produced, cannot do. I repeat it: four-fifths of the girls you present to society at fifteen cannot read a page intelligibly." But the current system of school-education is faulty and defective no less with regard to boys than with regard to girls, for, as Mr. Phillips further observes, "we produce only the superficial result of the culture we strive for. Now, I claim that this kind of education injures the boy or girl in at least three ways: first, they are able, only by forgetting what they have learned and beginning again, to earn their day's bread; in the second place, it is earned reluctantly; third, there is no ambition for perfection aroused. It seems to be a fact, which many of the public educators of to-day overlook, that seven-tenths of the people born into this world earn their living on matter and not on mind. Now, friends, I protest against this whole system of common schools in Massachusetts. It lacks the first element of preparation for life. We take the young girl or the young boy whose parents are able to lift them into an intellectual profession; we keep them until they are eighteen years old in the high schools; we teach them the sciences; they go to the academy or the college to pursue some course of preparation for their presumed course through life. Why not keep them a little longer and give them other than intellectual training for the business of life?"

Influence of Color of Soil on Potatoes.—Having observed that potatoes grown in dark-colored soil are less subject to disease than those grown in soil of lighter color, Mr. J. B. Hannay, member of the Edinburgh Royal Society, conjectured that the difference must be due to the greater absorption of heat by the darker soil. He accordingly made the following experiment: A piece of ground, consisting of a kind of blue till, was divided into two parts, both being planted with potatoes in the ordinary way. One of the parts was then covered with soot, which had been carefully washed till no soluble matter remained in it; the other part was left as planted. The potatoes in the soot-covered portion sprouted first, and throughout were much healthier than the others. The temperature of both portions was from time to time noted on sunny days with the following result:

	EARTH COVERED WITH SOOT.		PURE EARTH.	
	Depth, 2 In.	Depth, 8 In.	Depth, 2 In.	Depth, 8 In.
	55.4	52 6	53.0	52.1
	56.9	55.0	55.2	55.4
	67.2	63.9	65.1	60.8
	64.5	63.2	63.8	62.4
	61.7	58.7	58.8	58.0
	63.0	60.6	61.4	59.2
	58.1	56.9	57.2	56.3
	65.4	62.2	63.5	61.8
	63.2	63.8	63.9	62.0
	....	61.4	60.0	60.0
Average..	61.96	59.83	60.19	58.74

From this table it clearly appears that the potatoes grown in dark soil have a warmer climate, so to speak, than those in a light one. The tubers with no soot were weak, and had a great deal of disease among them, while the other lot were nearly all healthy.

Chemical examination showed the prin-

cipal inorganic constituents to be present in both in about the same proportions. There was a marked difference, however, between the two in the development of the starch-granules. In the potatoes grown under soot there was 22.5 per cent. of starch, but in the others only 17.5 per cent. —a difference of 5 per cent. Then, as for the size of the starch-granules in the good potatoes, the average was 0.175 millimetre; but in the diseased tubers it was only 0.155 millimetre. Thus it is seen that not only were the granules smaller, but their number was less. The inference is, that increase of temperature gives a great impetus to the growth of starch-granules both in size and number.

Asymmetry of the Eyes in Flounders.—The *American Naturalist* for December contains a singularly interesting paper by Prof. Alexander Agassiz on flounders, in which the author recounts his observations upon the manner in which the eyes, in that family of fishes, become placed on one side of the body. In five species of flounders he found that the eye on the blind side travels from its original place (symmetrical with the eye of the opposite side) frontward and upward on the blind side, resorbing the tissues in its way, and new tissues forming behind. This movement of translation is followed by a certain amount of torsion of the whole frontal part of the head, which, however, commences only after the eye of the blind side has nearly reached the upper edge of that side, quite a distance in advance of its original position. So far, Agassiz's observations concur, in the main, with the received theory. Further research, however, showed that the process of translation of the eye is not the same in all species of flounders. Having captured specimens about one inch in length, symmetrical and perfectly transparent, of the species *Bascania*, the author noticed after a few days that "one eye, the right, moved its place somewhat toward the upper part of the body, so that when the young fish was laid on its side the upper half of the right eye could be plainly seen, through the perfectly transparent body, to project above the left eye. The right eye (as is the case with the eyes of all flounders), being capable of very extensive vertical movements through an arc of 180°, could thus readily turn to look through the body, above the left eye, and see what was passing on the left side, the right eye being, of course, useless on its own side as long as the fish lay on its side. This slight upward tendency of the right eye was continued in connection with a motion of translation toward the anterior part of the head till the eye, when seen through the body from the left side, was entirely clear of the left eye, and was thus placed somewhat in advance and above it, but still entirely in the rear of the base of the dorsal fin, extending to the end of the snout.

"What was my astonishment on the following day," continues Prof. Agassiz, "on turning over the young flounder on its left side, to find that the right eye had actually sunk into the tissues of the head, penetrating into the space between the base of the dorsal fin and the frontal bone to such an extent that the tissues adjoining the orbit had slowly closed over a part of the eye, leaving only a small elliptical opening smaller than the pupil, through which the right eye could look when the fish was swimming vertically! On the following day the eye had pushed its way still farther through, so that a small opening now appeared opposite it on the left side, through which the right eye could now see directly, the original opening on the right side being almost entirely closed. Soon after, this new opening on the left increased gradually in size, the right eye pushing its way more and more to the surface, and finally looking outward on the left side with as much freedom as the eye originally on the left, the opening of the right side having permanently closed."

Destruction of Birds in the United States.—In the course of an article in the *Penn Monthly* on the decrease of birds in the United States, Mr. J. A. Allen says of the heron that, though nearly useless as food, it has been enormously diminished in numbers, mostly through natural causes, but in part by the wanton act of man. "Many," he writes, "have of late been destroyed for their feathers in Florida especially; the havoc made with these poor defenseless birds is a subject of painful contemplation

and a disgrace to the age. The poor birds are attacked at their breeding-grounds, and hundreds are slain in a few hours by single parties, whose only use of them is to secure the beautiful plumes with which Nature has unfortunately adorned them. In this way colony after colony is broken up, the greater part of the birds being actually killed on the spot, often leaving nestlings to suffer a lingering death by starvation. The few old birds that survive usually abandon the locality where for generations their progenitors had lived and reared their young undisturbed, only to be attacked at some new point the following year. The habit most of the species of herons have of breeding together in communities renders their destruction during nesting-time an easy matter, their strong parental affection leading them to be neglectful of their own safety when their young are in danger. Disgraceful and inhuman as the act may seem, many a heronry of the qua-bird, or night-heron, is annually destroyed in mere wantonness, in order that the perpetrator may boast of the 'cart-load' of birds he shot in a single day!"

The Plasticity of Ice. — Experiments made in 1871 by Prof. Bianconi, of Bologna, showed that slow changes of form in ice may be produced without any crushing or regelation, and that ice is, to a certain extent, plastic. He has lately published the results of further experiments on this subject, a brief notice of which is given in *Nature* as follows: "Granite pebbles and iron plates are slowly pressed into ice at the same temperatures, and not only do they penetrate into it as they would penetrate into a fluid or semi-fluid, but also the particles of ice are laterally repulsed from beneath the intruding body, and form around it a rising fringe. Moreover, when a flat piece of iron is pressed into the ice, the fringe rising around it expands laterally upon the borders of the piece, and tends thus, as in fluids, to fill up the cavity made by the body driven in. These experiments tend greatly to illustrate the plasticity of ice, but it would be very desirable that some measurements should be given, so as to obtain numerical values of the plasticity of ice under various circumstances."

Perils of Arctic Exploration.—Lieutenant Payer, one of the commanders of the Austrian Polar Expedition of 1872–'74, in his published narrative gives a graphic account of the perilous situation in which the expedition found itself on Sunday, October 13, 1872. "In the morning of that day," he writes, "as we sat at breakfast, our floe burst across immediately under the ship. Rushing on deck, we discovered that we were surrounded and squeezed by the ice; the after-part of the ship was already nipped and pressed, and the rudder, which was the first to encounter its assault, shook and groaned; but, as its great weight did not admit of its being shipped, we were content to lash it firmly. We next sprang on the ice, the tossing, tremulous motion of which literally filled the air with noises as of shrieks and howls, and we quietly got on board all the materials which were lying on the floe, and bound the fissures of the ice hastily together by ice-anchors and cables, filling them up with snow, in the hope that frost would complete our work, though we felt that a single heave might shatter our labors. . . . Mountains threateningly reared themselves from out the level fields of ice, and the low groan which issued from its depths grew into a deep, rumbling sound, and at last rose into a furious howl as of myriads of voices. Noise and confusion reigned supreme, and step by step destruction drew nigh in the crashing together of the fields of ice. Our floe was now crushed, and its blocks, piled up into mountains, drove hither and thither. Here they towered fathoms high above the ship; there masses of ice fell down as into an abyss under the ship, to be ingulfed in the rushing waters, so that the quantity of ice beneath the ship was continually increased, and at last it began to raise her quite above the level of the sea."

The Coal and Iron Resources of Alabama.—The coal and iron resources of Alabama were the subject of a recent interesting communication by Mr. William Gesner to the Academy of Natural Sciences of Philadelphia. According to the author, the coal-measures of the Warrior and Cahawba coal-fields consist severally of 172 and 173 strata. The coal-seams, which range from

one inch to six feet six inches in thickness, number 46 in the Warrior and 51 in the Cahawba field. Two beds of black-band ore characterize the Warrior measures, one of them showing 43 per cent. of metallic iron; clay iron-stone is abundant, and is found in all the Alabama coal-fields. In one instance it forms the roof of a 28-inch bed of coal in the Warrior measures. Immediately under the mountain limestone of the carboniferous formation in the Upper Silurian, a bed of fossiliferous hematite occurs. It extends in a northern direction over 120 miles into Tennessee. In Jefferson County, Alabama, its thickness is 28 feet. About two or three miles east and west of this ore-bed lie the coal-fields. For its entire extent throughout the State, and immediately under it, are the limestones of the Silurian formation, among which are many of the purest and those best adapted for fluxing iron from its ores. Geologically, in descending order, next come the immense beds of brown ore, comprising manganiferous and fibrous limonite and mamillary and crystallized hematite, from which hitherto nearly all of the iron of Alabama has been produced.

The Physical Properties of Gallium.—The physical properties of gallium, as ascertained by its discoverer, Lecoq de Boisbaudran, who has prepared a decigramme of nearly pure metal, are summed up as follows in the *American Journal of Science:* Its fusing-point is about 29.5 Cent., so that the heat of the hand liquefies it. When liquid, it exhibits the phenomena of surfusion to a remarkable degree. It has remained liquid for more than a month, the globule being frequently broken and reunited by a steel blade in a room the temperature of which often fell below the freezing-point. Contact with a bit of solid gallium, however, solidified it at once. Liquid gallium is very mobile, appears covered with a pellicle when exposed to the air, and adheres strongly to glass. Only a few degrees below its fusing-point the metal is hard and remarkably tenacious; but, like aluminum, it may be cut with a knife. It crystallizes with facility, crystal facets being developed by treatment with hydrochloric acid. It does not oxidize at a red heat except upon the surface, and does not volatilize. Its spark-spectrum gives the two well-known bright lines of wave-length 417 and 403.1; its flame-spectrum only the 417 line, and this difficultly. Its density approximately is 4.7, thus placing it, like its other physical properties, between aluminum and indium. Its atomic weight places it there probably also.

Death of Karl Ernst von Baer.—The eminent Russian zoölogist, Karl Ernst von Baer, died at Dorpat, November 28th, in the eighty-fifth year of his age. He was born at Piep, in Esthonia, in 1792; at the age of eighteen he entered the University of Dorpat, graduating four years later as doctor of medicine. He then went to Germany, and, at Würzburg, became a pupil of Döllinger, the eminent professor of physiology and anatomy. This was the turning-point in Von Baer's career, and determined the course of his future studies. In 1817 he became prosector at Königsberg, and, four years later, professor of zoölogy. In 1830 he returned home, having been elected a member of the St. Petersburg Imperial Academy. He conducted a scientific exploration of the northern shores of Russia in 1837. Of his most celebrated work, "The Development History of Animals," the first volume appeared in 1828 and the second ten years later. He was also the author of numerous treatises on the zoölogy and botany of Russia. His latest work was an adverse criticism on the Darwinian theory.

The death of Alexander Bain, which took place at Glasgow, January 2d, was cabled to this country, and at once interpreted as applying to the eminent Professor of Logic in Aberdeen University, who bears that name, and who is much more widely known here than Alexander Bain, the electrician, to whom the dispatch referred. He was an inventor, and made various important improvements in telegraphy. He invented, or reinvented, the method of making use of "bodies of natural waters to complete the electric circuit by laying a single insulated wire between the given stations, having at each end a metallic brush immersed in the water." This principle was promulgated in a patent of 1841. In 1846 he patented the electro-

chemical telegraph, and soon found his system capable of great speed; he was thus led to the invention of automatic methods of transmitting signals, of which one is the basis of the most important process now used. He invented electrical clocks, and in 1843 constructed the earth-battery. In 1844 he patented ingenious apparatus for registering the progress of ships, and he also devised electrical methods of playing keyed instruments at a distance. He was struck down with paralysis some years ago, and died, at the age of sixty-six, in a "Home for Incurables." A Government pension of eighty pounds a year was all that saved him from pauperism.

NOTES.

Mr. Seth Green, of Rochester, Fisheries Commissioner, announces that he is ready to supply brook and salmon trout to persons who desire the same for the purpose of restocking the waters of the State of New York. Applicants must remit to Mr. Green money to pay the traveling expenses of a messenger, and full directions as to the route to be taken.

Benjamin R. Tucker, of New Bedford, Massachusetts, proposes to issue, early in the present year, the first number of a quarterly periodical, to be known as the *Radical Review*, and modeled after the *Fortnightly* and the *Contemporary Review* of London. The list of contributors includes the names of many of the foremost American radicals. The subscription price will be $5 per annum.

In an address before the Illinois Wool-Growers' Association, Mr. George Lawrence, Jr., of Wisconsin, asserted that merino sheep, taken from Vermont to Wisconsin, show a marked improvement in many respects when bred in the latter State. They have a larger carcass, are heavier boned, quality and quantity of fleece are equal if not superior, and they are more hardy, than their Vermont ancestors.

The Bulgarian Turk of the lower class believes that a railway-engine is driven, not by steam-power, but by a devil. A young devil is trapped in England, shut up in the "fire-box on wheels," and bribed to work the crank by the occasional gift of a little cold water to mitigate his torture.

M. Drouyn de Lhuys, President of the French Agricultural Society, has issued a circular to similar bodies in foreign countries, announcing that the society intends to organize an International Agricultural Congress to assemble at Paris during the Exposition of 1878.

The award of the London Royal Society's medals for 1876 was as follows: To Claude Bernard, the Copley Medal for physiological researches; a Royal Medal to William Froude, for researches on the behavior of ships; Royal Medal to Sir C. Wyville Thomson, for services on board the Challenger; Rumford Medal to P. J. C. Janssen, for researches in the radiation and absorption of light.

Prof. Osborne Reynolds, in reply to some newspapers which have pronounced the British Arctic Expedition a failure, calls attention to the fact that, since Hudson's time, arctic navigators had penetrated 60 or 70 miles of the 540 to be passed on the route to the pole. But Captain Nares has in one year carried the British flag 60 miles nearer, so that "nearly one-half, and this by far the most difficult half, of the entire results of all expeditions since Hudson's time, has been accomplished by the last." Further, Captain (now Sir George) Nares seems to have pursued his journey to its end, at least by that route; and in coming back can say that he did not leave a single uncertainty behind him.

A very valuable mine of silver has recently been discovered at Harbor Island, Newfoundland, near the public wharf.

An act of the Parliament of the Dominion of Canada grants an additional quarter-section of land, on payment of a trifling fee, to every settler on Dominion lands who plants with trees thirty-two acres in successive annual installments.

Dr. A. E. Foote has established at 3725 Lancaster Avenue, Philadelphia, an agency for the sale and exchange of natural-history specimens, including minerals, botanical and zoölogical forms, fossils, prehistoric relics, etc. He issues a monthly bulletin containing the needed particulars, and which may be obtained on application.

An eminent scientific professor, interested in the state of science-education in our colleges, has been looking into the subjects of their use of text-books. He collected catalogues from 187 colleges, and gleaned from them the following statistics regarding the physical and chemical text-books employed. For physics, the text-books ran thus: Olmsted in 48 colleges, Ganot in 33, Silliman in 16, Steele in 15, Deschanel in 12, Rolfe and Gillette in 11, Wells in 8, Norton in 8; the others scattering. The preferences for chemistry ran as follows: Youmans in 37 colleges, Eliot and Storer in 28, Barker in 24, Roscoe in 18, Steele in 18, Fownes in 13, Wells in 10; others scattering.

A tame crow, in the possession of a writer in the *Nuttall Ornithological Club Bulletin*, rids himself of parasites in a very ingenious way. He takes his stand on an ant-hill, and permits the ants to crawl over him and carry away the troublesome vermin. The same habit was observed in another tame crow formerly in the author's possession.

Died in Indianapolis, December 12, 1876, Prof. Herbert E. Copeland, aged twenty-seven years. His scientific studies were commenced at Cornell University, where he devoted himself chiefly to natural history, graduating Ph. B. in 1872. He then became, successively, principal of an academy at Ravenswood, Illinois, and Professor of Natural Sciences in the normal school at Whitewater Wisconsin, and in the high-school at Indianapolis. His premature death was the result of exposure while studying the ichthyology of the State of Indiana in company with Prof. Jordan.

It is proposed in California to establish at numerous points in the State experiment-stations for the purpose of accurately determining sundry agricultural problems, such as the nature of the soils of different localities, the best mode of maintaining and restoring productiveness, etc.

A fearful epizoötic prevailed last fall among the horses of Egypt. On the 18th of September 200 horses died in Cairo alone. The army-horses were specially afflicted, and 50 per cent. of them had died before the end of September. The carcasses were transported into the desert and thrown into those enormous bone-quarries of which we can have no idea here. But many were cast into the canals, and the consequences may be disastrous. It is supposed that this equine plague came from Abyssinia.

Prof. Leidy, in dredging the bottom of the Schuylkill near its mouth, was surprised to observe that no living thing whatever was brought up, the mud and sand being black and saturated with bituminous oil. The refuse of the city gas-works and probably of some coal-oil refineries run into the river. The oils appear to have an affinity for the suspended particles of clay, and the result is a bituminous sediment. In the same manner oils from decomposing animals, and also from certain plants, may have supplied the sedimentary muds of ancient shales.

A radiometer, in the shop of a Paris optician, during the first two weeks of December, twice stopped entirely in the daytime—viz., on the 8th, during a thunder-storm, and on the 13th, during a fog. The instrument varied considerably as to the moment of daily commencing to revolve—the extremes being 8.15 and 10.25 a. m. The time of stopping was far less irregular—the variation being only from 3.30 to 4 p. m.

Most of the monthly educational journals in the Western States have been consolidated to form one strong weekly—the *National Journal of Education*, published in Chicago. The editors are W. F. Phelps, editor-in-chief, Prof. E. Olney, and others. Special editors will be employed to conduct special departments. The subscription price of the *Journal* is $2.50 per year.

In the hope of eliciting further information concerning the breeding-habits of the American kinglets (*Regulus*), or at least of putting observers upon the alert for further information, Mr. Ernest Ingersoll publishes, in the November number of the *Bulletin of the Nuttall Ornithological Club*, a paper in which is brought together whatever is at present known respecting the nidification of these birds.

In consequence of the extraordinary precautions taken last Fourth of July, the losses by fire from the use of fire-works were less than usual on that anniversary; but the losses so caused were nevertheless enormous. In the report of the National Board of Underwriters it is stated that the invoice value of all fire-crackers imported since January 1, 1875, is less than $1,500,000, and that the loss by two conflagrations traceable directly to them amounts to upward of $15,000,000! It is considered to be not an extravagant statement that every dollar's worth of fire-crackers imported into this country occasions a direct loss by fire of more than $100.

In order to reduce to the minimum the danger to health incurred by workmen employed in the manufacture of white-lead, the British Inspector of Factories recommends that clothes, gloves, and caps, should be provided for the employés to be worn in the works; water-proof boots for those working with the moist white-lead, and respirators for those working with the dry white-lead. Besides, no workman should be allowed to leave the works unwashed, or in the factory-dress.

There appears to be at present a considerable degree of religious fermentation in Russia, and sects of all kinds are daily springing up. One of these new sects, the Philipovtzi preach suicide by fire and starvation as the greatest of Christian virtues. The "Child-Murderers" think it their duty to people paradise with the souls of innocent children. The "Stranglers" believe that people can only enter paradise by a violent death. Other sects are the "Flagellants" and the "Skoptzi," or mutilates. The Skoptzi number about 100,000 persons of both sexes.

WILLIAM CROOKES, F.R.S.

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A COMBAT WITH AN INFECTIVE ATMOSPHERE.[1]

By Professor JOHN TYNDALL, F. R. S.

A YEAR ago I had the honor of bringing before the members of the Royal Institution some account of an investigation in which an attempt was made to show that the power of atmospheric air to develop life in organic infusions—infusions, for instance, extracted from meat or vegetables—and its power to scatter light went hand-in-hand. I then endeavored to show you that atmospheric air, when left to itself, exercised a power of self-purification; that the dust and floating matter that we ordinarily see in it disappeared when the air was left perfectly tranquil; and that, when the air had thus purified itself, the power of scattering light and the power of generating life had disappeared together. For the sake of reminding you of this matter, we will now cause a beam of the lamp to pass through the air. You see the track of the beam vividly in the air. You know that the visibility of the track is not due to the air itself. If the floating matter were removed from the air, you would not be able to track the beam through the room at all. You see the track in consequence of the floating dust suspended in the air. If the air be inclosed in a place free from agitation the dust subsides, and then, as I endeavored to show you a year ago, the air possesses no power of generating life in organic infusions. The nature of the argument is this: You see the dust as plainly as if it were placed upon your hand, and you could feel it with your fingers. You found that the dust, when it sowed itself in organic infusions, produced a definite crop in those infusions; and you are equally justified in inferring that the crop thus produced is due to the germs in the dust, as a gardener would be in believing that a certain crop is produced from the seeds which he

[1] A lecture delivered at the Royal Institution, on Friday, January 19, 1877.

sows. I say that the inference that his crop is the product of the seeds that he sows is not more certain than the inference that those crops produced in the organic infusions are due to the seeds contained in them.

You know the method that we resorted to for the purpose of enabling us to get rid of this dust. The object was, to allow the air to purify itself, and it was done in this way: I have here the first chamber that was used in these experiments. You see at the bottom a series of test-tubes entering the chamber; they are air-tight, and they open into it. There are windows at the sides, and here is a pipette through which the liquids can be introduced. Behind we have a door which opens upon its hinges. Now, imagine this perfectly closed; imagine it abandoned entirely to itself, left perfectly quiet. In a few days, the floating dust of the air contained in the chamber entirely disappears—it has removed itself by its own subsidence—and then, when you send a beam of light such as we have here through these windows, you see no track of the beam within the chamber. When the air is in this condition, you pour through this pipette infusions of beef, mutton, or vegetables, into these tubes, and allow them to be acted upon by the air. Last year, between fifty and sixty of these chambers were constructed, and the invariable result was that these infusions never putrefied, never showed any change, were perfectly sweet months after they were placed there, as long as the air had this floating matter removed. You had nothing to do but to open the back-door and allow the dust-laden air to enter the chamber to cause these infusions to fall into a state of putrefaction, and swarm with microscopic life, in three days after opening the door. I have a smaller chamber here—for we use chambers of different sizes—and it will enable you to understand our exact process. (*See* Fig. 1.) You see here the stand on which the chamber rests. There are two bent tubes that communicate with the outer atmosphere, for I wish to have a free communication between the air outside and the air within. You see the pipette through which the tube is filled. When the infusion is poured in, you place it in an oil-bath contained in a copper vessel, such as we have here, in which you boil it for five minutes. Now, that boiling for five minutes was found capable of sterilizing every germ contained in the infusions placed in these chambers. This year our experiments began by a continuation of those that we made last year. In order to enable you to judge of the severity of the results obtained last year, I have here five cases belonging to the experiments then made. You will see that the infusions are vastly concentrated because of their slow evaporation. The quantity of liquid is reduced to one-fifth of its primitive volume, but this one-fifth is as clear as rock-crystal; whereas, the tubes exposed to the ordinary air outside fell long ago into utter putrefaction. They became turbid and covered with scum, and when you examine these

infusions to ascertain the cause of that turbidity, you find it to be produced by swarms of small active organisms.

This year our inquiries began in the month of September. But we will pass over these inquiries for the moment and go to those of October. On October 29th, two members of the Royal Institution collected a quantity of fungi in Heathfield Park, Sussex. These were

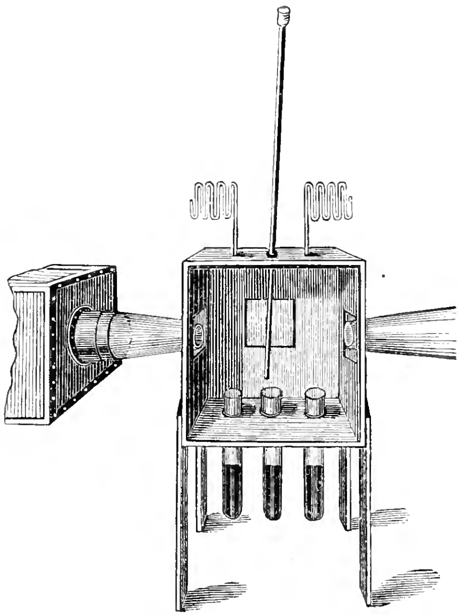

FIG. 1.

brought to London on the 30th. They were placed for three hours in warm water, and, whatever juices they possessed, were thus extracted from them. They were placed in chambers and digested separately. There were three kinds of fungi; we will call them red, yellow, and black. Now, I confess that, thinking I had secured a perfect freedom from any invasion of those contaminating organisms that produce putrefaction, I expected that we should find that these infusions of fungus would maintain themselves perfectly clear. To my surprise, in three days the whole of them broke down; they became turbid, and covered by a peculiar fatty, deeply indented, corrugated scum. Well, that was a result not expected, but I pursued the matter further. I got another supply of fungi. Even in this first experiment, I had used care at least as great as that which I adopted last year, and which led to a perfect immunity from the invasion of putrefaction. With the fresh supply of fungi, I operated with still more scrupulous care. The infusions were placed as before in three chambers. In one of these, the infusion remained perfectly pellucid;

there was no trace of any organism to be seen. In each of the other chambers one of the three tubes gave way. Each chamber contained three tubes; so that, out of nine tubes containing an infusion of fungus, seven proved to be intact, entirely uninvaded. Therefore, whatever argument or presumption was raised by the first chamber in regard to the idea that life was spontaneously generated in it, was entirely destroyed by the deportment of the other chambers. Seven out of the nine remaining intact, was sufficient to show that it was some defect in the experiment that caused the first chambers to give way so utterly. I continued the experiments, and, inasmuch as fungi disappeared on the approach of winter, other substances were chosen. I took cucumber and beet-root, having special theoretical reasons for doing so, and prepared infusions of them with the aid of my excellent assistant Mr. Cotterell. We placed these in our chambers as before, boiled them for five minutes, and abandoned them to what I supposed to be the moteless air within. Again, to my surprise, an infusion of beet-root in one chamber, and an infusion of cucumber in another, broke down. All the tubes became turbid and covered with this peculiar fatty scum. Other chambers were then tried. I had begun to suspect that we were operating in a contaminated atmosphere; that my infusions were in the midst of a pestilence which it was hardly possible to avoid. The consequence was, that I withdrew the preparation of the infusions from the laboratory down-stairs, and I went to one of the highest rooms in the Royal Institution, had the infusions prepared there, and introduced into the cases, which were afterward boiled in the laboratory below. There were a great number of these cases. The substances chosen were cucumber, beet-root, turnip, and parsnip. Great care was taken to have the infusions properly prepared, and to have them rendered as clear as possible. To give you an idea of the care taken, I may mention that the infusions of turnip and beet-root were passed through 24 layers of filtering-paper, and were thereby rendered clear; that the infusion of cucumber was passed through 120 layers of filtering-paper, and thereby rendered clear; and that the infusion of parsnip was passed through 300 layers of filtering-paper, and it was still opalescent. The suspended particles were so small that the filtering-paper had no power whatever to arrest them, and the finest microscope ever made would have proved powerless to exhibit the individual particles that produced this opalescence. Notwithstanding all this care, the chambers containing these infusions in three days became filled with bacterial life. They were turbid, covered with scum, and showed all evidences of putrefaction. This was on November 20th. On November 25th we went up-stairs and prepared another chamber, or a series of chambers. When the tubes containing the infusions were placed in the oil-bath, the liquids within the tubes opening into the case of course boiled, steam was discharged into the case, the air of the case being thereby rendered warm. It

was found that on the cessation of the ebullition, although the pipette was immediately plugged with cotton-wool, and the bent tubes also plugged with cotton-wool, still, in consequence of the contraction of the air within, there was a considerable indraught. Last year, we found invariably that the interposition of the cotton-wool entirely sifted this entering air so as to arrest any germs or seeds that it might contain. I thought, however, in this case, that the germs might be carried in by the suction when the air of the chamber contracted. In the former case, we operated after having filled the chamber with the infusion and boiled it in the laboratory; in this case, we took the additional precaution of boiling the infusion up-stairs, and taking care that it was properly plugged with cotton-wool. But here, again, notwithstanding this augmented care, the infusion utterly gave way, and showed those evidences of life that had distracted me previously. When I say distracted, it is not meant that I was in the least degree daunted or perplexed about it. I knew perfectly well that the matter would be probed by-and-by. On November 27th a new chamber was constructed containing cucumber and turnip. Particular care was taken with the stopping of the pipette, and also the bent tubes opening into the atmosphere. In one instance, about this time, it was noticed that the infusions in the tubes within the chamber opening into the moteless air, or at least what I supposed to be the moteless air, fell more rapidly into a state of putrefaction, became more rapidly covered with scum, than the tubes exposed in the air outside. When the tubes containing precisely the same infusion were exposed to the air outside, they were perfectly clear, while those within were turbid and covered with scum. This brought to my mind an experiment made the previous year with trays placed one above the other.

It was found that, when two trays were placed one above the other, although the upper tray had the whole air of the room for its germs to deposit themselves, the under tray was always in advance of the upper in the development of life. The reason was simply this: The air in the under tray was less agitated, and this floating matter had time slowly to sink in the infusions. There was no other solution possible than that, by some means or other, the germs had insinuated themselves into my chamber, and that these germs, sinking slowly through the unagitated air of the chamber, were able to produce the effect within in advance of the effect produced upon the openly-exposed tubes without. On November 27th I had a similar case, and also on November 30th, and on December 1st. The chambers were prepared and filled with all care, and yet the infusions broke down, became turbid, and were covered with scum. I then had a number of tubes filled with infusions, and sealed them hermetically. They were exposed in an oil-bath, and heated for a quarter of an hour to a temperature of 230° Fahr., for I wanted to see whether these effects were due to any germs of life in the infusions themselves. This superheated

cucumber-infusion was introduced into the chamber, and it was found that the superheating of the infusion did not even retard the development of life. In two days every tube of the chamber was swarming with bacteria. I then passed on to another system of experiment pursued last year, that is, the exposure of the infusions to air calcined by passing a voltaic current through platina-wire, so as to raise the wire to a state of incandescence. Such arrangements are here. We have underneath this shade two wires, and stretching from wire to wire we have a spiral of platinum. Passing a voltaic current through the spiral, it was found last year that five minutes of incandescence were sufficient entirely to sterilize and destroy all germs contained in this air, and to protect the infusions underneath from all contamination; the time of incandescence was doubled this year. The wire was raised as close to the point of fusion as possible; still, notwithstanding all this additional care, the infusions one and all gave way. I thought that there might be some defect in the construction of the apparatus. Here, you see, is an old broken apparatus containing infusions that have remained perfectly good since last year; but great pains were taken in having the apparatus of the most improved form. Still, notwithstanding all my efforts, the infusions broke down and became swarming with life. My attention was now very keenly arrested, and on December 1st I scrutinized more closely than ever I had done previously the entry of the infusions through the pipette-tube into the tubes opening into the chamber, and I noticed, at all events, a danger of minute air-bubbles being carried down along with the descending infusion. That caused me to adopt another mode of experiment; but, previously to this, I fell back upon some of the infusions found so easy to sterilize the previous year. I operated upon beef, mutton, pork, and herring infusions, and found that even such infusions, which with the most ordinary care were completely sterilized last year, and are preserved to the present hour intact like the others, all gave way.

How, then, are we to look at these things? Here are results totally different from those that we obtained last year. You may ask me, perhaps: "Why do you not loyally bow to the logic of facts and accept the conclusion to which those experiments apparently so clearly point? Why do you not regard them as a demonstration of the doctrine of spontaneous generation? Is there any other way of accounting for it than by a reference to this doctrine?" You may ask whether I was held back by prejudice from accepting this conclusion, whether I was held back by a love of consistency, or by the fear of being turned into ridicule and sneered at by those whom I ventured to oppose on a former occasion. Ladies and gentlemen, there is a title which I believe, as the generations pass, will, if the owners of the title are true to themselves, become more and more a title of honor—that is, the title of a man of science—and of that title I should

be utterly unworthy were I not prepared to trample all influences and motives such as those mentioned under foot, and were I not ready, did I conceive myself to be in error in what was brought before you last year, to avow here frankly and fully in your presence that error. I should be unworthy of the title of a scientific man if my spirit had not been so brought into this state of discipline as to be able to make such an avowal. Why, then, do I not accept those results as proving the doctrine of spontaneous generation? The celebrated argument of Hume comes into play here. When I looked into all my antecedent experience, and into the experience of other men for whom I have the greatest esteem as investigators, it was more easy for me to believe the error of my manipulation, to believe that I had adopted defective modes of experiment, than to believe that all this antecedent experience was untrue. It was my own work that was thus brought to the bar of judgment, and my conclusion was, that I was far more likely to be in error than that the great amount of evidence already brought to bear upon the subject should be invalid and futile. Hence, instead of jumping to the conclusion that these were cases of spontaneous generation, I simply redoubled my efforts to exclude every possible cause of external contamination. This was done by means of doing away with the pipette altogether and using what we call a separation-funnel. Here you have a chamber with a pipette entering. This pipette-tube has not a bulb or mouth such as you have here; it is simply closed by a tube of India-rubber, and that again is closed by a pinchcock. Now, here we have an infusion of hay. At present this stopcock stops it. I turn it on; it goes down; I turn it off, and this liquid column is now held by atmospheric pressure. This was introduced into the India-rubber tube, the India-rubber tube being first filled with the infusion, so that no bubble of air could get in. When the separation-funnel was placed thus and the cock was turned on, the liquid was introduced into the chamber without an associated air-bubble. Mr. Cotterell will show you the result of this severe experiment. Here is an infusion of cucumber, the most refractory of all infusions that I have dealt with. It was prepared on December 8, 1876, so that it is between six and seven weeks old. Two days were sufficient to break down this infusion when contamination attacked it; but, by this more severe experiment, it is enabled to maintain itself as clear as crystal, although it has been there for six or seven weeks. You will see by the light behind that it is, as I have described it, perfectly clear. You will observe that the infusion is diminished by evaporation, but it is as clear as distilled water, and there it remains as the result of this severe experiment.

Let us now ask how it is that these curious results that I have brought before you were possible; how it is that the results of this year differ so much from those obtained previously. The investigation of this point is worthy of your gravest attention. I am now

called back to the experiments with which the inquiry this year began. As already stated, it was begun in September, and, leaving out the earlier experiments, I passed on to October 30th. I have now to bring your attention back to the earlier experiments performed in the laboratory. They were suggested by the ingenious investigations of Dr. William Roberts, of Manchester, and by the subsequent investigations of a man to whom we are indebted more than to any other for the knowledge we possess of the different species of those small organisms that we call bacteria; I refer to Prof. Cohn, of Breslau. Let me say that I entertain the very highest opinion of the intelligence and ability with which Dr. Roberts has carried out these experiments; they are in the highest degree creditable to him. This is the experiment to which I refer: Some chopped hay is put into a little can; it is raised to a temperature of 100° to 120°; it is kept for three hours, then poured off and filtered. Last year, we found that hay thus treated was sterilized by five minutes' boiling. I mean that, when it is exposed to the air that has this floating matter removed from it, it never shows any sign of microscopic life. Now, if you examine this natural hay-infusion with litmus-paper, you will find that it turns the litmus-paper red, showing that it is an acid infusion. Dr. Roberts found that acid infusions could be easily sterilized, and his mode of proceeding will be evident from the figure that I have here drawn. He took a vessel with an open neck at the top (*A*, Fig. 2), and filled it two-thirds full with the infusion he wanted to operate upon; he then stuffed the neck with cotton-wool, and sealed it hermetically with a spirit-lamp above the plug of cotton-wool (*B*, Fig. 2); he then placed it in a vessel containing cold water, and he gradually raised the water to a state of ebullition and maintained the boiling temperature for any required time. In that way he avoided all commotion, all evaporation, all ebullition in the infusion. After he had placed the tube in this condition in the water, and subjected it to a boiling temperature for any required time, he took it out and simply filed across the neck and broke it off, as I do with this one (*C*, Fig. 2). Here you have the infusion practically exposed to the atmosphere. The plug intervenes to prevent the entrance of dust, and still allows an interchange between the air of the bulb and the air outside. When Dr. Roberts took this acid infusion and neutralized it by the addition of caustic potash, he found it to possess the most extraordinary power of resistance to heat; he found that, in some cases, it required more than two hours to reduce this infusion to sterility; he also found that, in a particular case, it actually required no less than three hours' boiling to produce this effect. This was very different indeed from the results that I had obtained last year. I made many experiments with hay-infusion, and in every case we sterilized it by five minutes' boiling. I was led to take up the subject this year through the emphatic manner in which Prof. Cohn corroborated the results of Dr. Roberts.

I operated sometimes with tubes like those of Dr. Roberts, and sometimes with those which I call Cohn's tubes. These are formed by heating a certain portion of a test-tube and drawing it out so as to leave an open funnel above, a bulb below, and a narrow tube between both. These are Cohn's tubes. His method was this: He placed the tubes, as they are placed here, in boiling water, and, when they had been subjected to a boiling temperature for a sufficient time, he

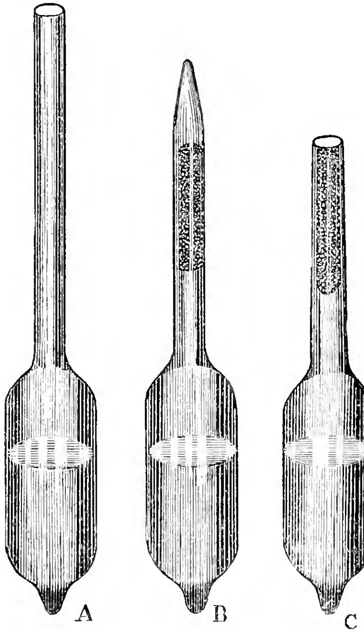

Fig. 2.

simply lifted them out. He found a certain amount of water condensed upon the neck of the bulb; he waited one or two minutes until that evaporated, and then quietly plugged his tube with cotton-wool, and he thought that this was perfect immunity against the entrance of contamination; and Prof. Cohn is very emphatic in saying that there is no thought of contamination from without in pursuing this method of experiment. I operated upon a great variety of hay-infusions, and after a time, by pursuing with the most scrupulous exactness the method laid down by Dr. Roberts and Prof. Cohn, it was possible for me, by practice, now to corroborate and now to contradict them. It is perfectly useless to bring forward before public assemblies merely opposing assertions, so that I did not really content myself with falling back upon the results I obtained last year, but tried to get some knowledge as to whence the differences arose which showed themselves between me and these distinguished men. Here

are tubes of alkalized hay, some of them subjected to a boiling temperature, not for three hours, but for ten minutes, and they are perfectly brilliant; there is not the slightest evidence of life in them; they have been entirely sterilized by an exposure to a boiling temperature for ten minutes. If I illuminate them, you will find that these infusions are perfectly brilliant; there is no turbidity that gives any sign of the production of animalcular life. These tubes have remained there for three months perfectly intact, uninvaded by those organisms which were invariably found both by Dr. Roberts and by Prof. Cohn. Again, we turn to another series of tubes, and find that every one of them has given way. Thus I went on ringing the changes, until, as I have said, it was in my power, by pursuing with undeviating fidelity the mode of experiment laid down by Dr. Roberts and Prof. Cohn, to get at one time a contradiction, and at another time a corroboration of their results.

And what was the meaning of these irreconcilable contradictions? The meaning was this: when we came to analyze these various infusions, we found that those that were sterilized by a boiling of from five to ten minutes were invariably infusions of hay mown in the year 1876, whereas the others were infusions of hay mown in 1875 or some previous year. The most refractory hay-infusion that I have ever found was in the case of some Colchester hay five years old. Now, what do these experiments point to? The answer may be in part gathered from an observation described in the volume of the *Comptes Rendus* for 1863, by one of the greatest supporters of the so-called doctrine of spontaneous generation. A description is here given of an experiment that was made by the wool-staplers of Elbœuf. They were accustomed to receive fleeces from Brazil, which were very dirty, and had, among other things, certain seeds entangled in them. These fleeces were boiled at Elbœuf sometimes for four hours; and the seeds were afterward sown by some of these expert fellows that had to deal with the fleeces, and were found capable of germination. The thing was taken up by Pouchet. He gathered these seeds, exposed them to the temperature of boiling water for four hours, and then examined them closely; and he found (and I recently made an experiment which showed the same thing to be true with regard to dried and undried peas) that the great majority of the seeds were swollen and disorganized, while the others were scarcely changed; they were so indurated, and perhaps altered in the surface, as to prevent the liquid from wetting them. At all events, a number of them appeared to be quite unchanged. He separated these two classes of seeds and sowed them side by side in the same kind of earth. The swollen seeds were all destroyed; there was no germination; but in the case of the others there was copious germination. Here, then, you have these seeds proved to be capable, by virtue of their dryness and induration, of resisting the temperature of boiling water for four hours. There is

not the slightest doubt that, if time permitted, I could heap up evidence of this fact, that the wonderful sterility of this old hay is due to the induration and desiccation of the germs associated with it. Here you have three tubes containing cucumber-infusion of crystalline clearness; they have been simply subjected to a boiling temperature for ten minutes; they have been completely sterilized, and they are as clear as when the infusions were first introduced into the tubes. On the other hand, here are tubes that have been subjected to a boiling temperature for five hours and a half, showing a swarming development of life. What is the reason of this difference? The reason depends entirely upon the method of experiment. When Dr. Roberts filled his bulbs, he simply poured in his infusion, plugged his tube, sealed it, and subjected it to a boiling temperature. Not only did the liquid contain germs, there was a quantity of air above the liquid, and the germs were diffused in the air. Germs thus diffused in the air are very differently circumstanced from germs diffused in a liquid;

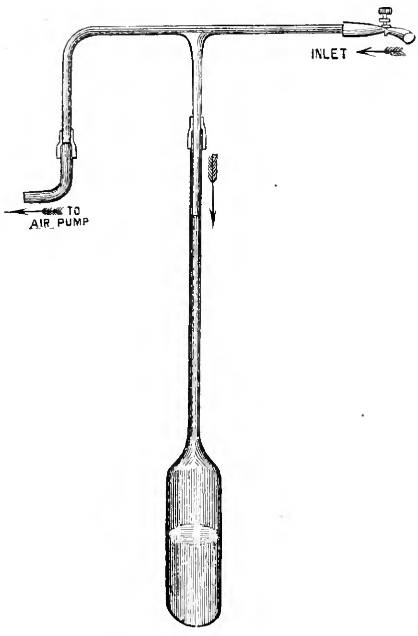

FIG. 3.

they can withstand for hours a boiling temperature; whereas that self-same temperature, brought to bear upon germs immersed in liquid, destroys them in a few minutes. And why do these tubes differ? The reason is to be sought entirely in the method of filling the tubes containing the clear infusions. Here is a diagram (Fig. 3), representing one of Dr. Roberts's bulbs. You see that the top is united to a T-piece with a collar of India-rubber. This comes down and ends in

the neck of the bulb. Here is an air-pump, and here is the end of the T-piece surrounded by a tube of India-rubber, and here is a pinchcock to close that tube of India-rubber. If you open the pinchcock and work the air-pump with which this end is connected, it is completely exhausted. You may allow it to be filled with air; you may then open the pinchcock: the air will enter through the cotton-wool, and will fill the bulb. In this way you get the bulb filled, not with common air, but with filtered air. This process is carried on three or four times, so as to make sure that the common air has been displaced by the filtered air. We will suppose that I detach the tube from the air-pump, and other precautions taken. At present, you see the bulb is empty. Taking an infusion of hay, I put the end of the T-piece into the infusion to be introduced into the bulb. The bulb is dipped into hot water; the air expands, and it is driven out. Simply introducing our bulb into cold water, the air shrinks, and by atmospheric pressure the liquid is driven into the bulb. Again we drive the air out, and, by a few operations of this kind, we find that we can charge our bulb with a very great degree of accuracy. You can see the liquid in the bulb at the present time. In this way we charge a bulb which has had its common air and floating matter removed with our infusion. When it is charged, it is very carefully removed, and great precautions are taken so as to prevent any indraught of air. For instance, it is always removed from the cold water, so that, when it is lifted up into the air of the laboratory, a slight expansion shall take place, so that the motion of the air shall be from within outward, instead of from without inward. In that way we can, by careful manipulation, obtain bulbs devoid of this floating matter. These are the bulbs you now see before you showing this beautifully pellucid infusion.

Were this a biological investigation, and not a physical one, I should feel myself out of my element in dealing with it. I leave the determination of the species of bacteria to others far more competent than I am. I can see these organisms and wonder at them when I see them through the microscope; but I have no ability or knowledge to classify them and divide them into species, genera, etc. But these are purely physical experiments, and it is only by such severe experiments that this question can be freed from the haze and confusion in which it has been hitherto involved. Even the celebrated Prof. Cohn—I say it with the greatest regard and respect for him—appears to have no adequate notion of the care necessary to be taken in experiments of this kind. To lift a tube out of the boiling liquid and allow it to remain quietly in the air, the entry of the air taking place from without inward, and then, after one or two minutes' exposure, to plug it with cotton-wool, and say that no contamination can reach it, is in my opinion a great mistake. He could not, but by the merest accident, get an infusion free from contamination by operating in this way. I have here tubes prepared according to this method. Here

are some melon-tubes all putrid, all gone into a state of fermentation. I ask you to compare those with some other melon-tubes that I have operated upon in a different way and that are as clear as crystal. The others are all gone, simply through a defect in the mode of manipulation.

The defeats that I at first described to you were due entirely to the contaminated atmosphere in which we worked. It ought to be noted that, in the earlier experiments in this inquiry, the results were always in accordance with those brought before you last year. By degrees, however, masses of hay were introduced into the laboratory—old hay and new hay from various places; and they ended by rendering the atmosphere so virulently infective that everything was contaminated by the germs set afloat. It resembled the case of a surgical ward of a hospital, where gangrene and putrefaction have attained such a predominance that the surgeon has, in despair, to shut up his ward and abandon it to disinfection. Desiring to free myself from this pestilential atmosphere, I wrote to my friend the President of the Royal Society, Dr. Hooker, and I found that he was able to furnish me with a means of getting away from it. In Kew Gardens, there is a beautiful new laboratory, erected by the munificence of that most intelligent supporter of science, Mr. Thomas Phillips Jodrell. He, at his own expense, has had this beautiful laboratory built—being designed, I believe, by Dr. Thiselton Dyer. It is one of the neatest things I have ever seen, and it is to me a great gratification that the first experiments made in that laboratory were those to which I have now to refer. I broke away from the contaminated air of the Royal Institution. It is very well for you that I can tell you that all the germs referred to are perfectly innocuous to human beings, for I have no doubt the air of this room is contaminated with them. A series of chambers was made—not of wood, for I wanted to get rid even of that, but of tin—and I would not allow Mr. Cotterell to carry those chambers into the Royal Institution at all. They were carried from the tinman's where they were made to the laboratory at Kew. There, with the greatest care, the tubes were treated first with carbolic acid and then washed with water, and then with caustic potash to get rid of all traces of carbolic acid, and finally drenched with distilled water. Carbolic acid, as you know, is a deadly foe to these germs. In this way I hoped that every contamination that might be adhering to the tubes would be destroyed, and that, having got clear of an infected atmosphere, we might get the same results as we invariably obtained last year. The temperature was raised to between 80° and 90°, and once a little above 90°, so that the warmth was all that could be desired for the development of those organisms. It gives me the deepest gratification to find that what was foreseen has occurred, and that this very day these chambers have come back from Kew perfectly intact. They comprise the most refractory substances that I had experimented

upon here. It was almost impossible to save a cucumber; I never did succeed in saving a melon infusion from contamination, and from this so-called spontaneous generation. But here, when the air had been allowed to deposit all its motes, and when we were withdrawn from an infected atmosphere, as I have said, the chambers were returned with their infusions as clear as crystal. Mr. Cotterell will show you some of them. You will see that one of these is muddy and turbid, and it has a deposit at the bottom. These are all dead bacteria, and the muddiness is due to swarming bacterial life. Here you have two infusions perfectly clear. Why does the other tube give way? When we came to examine it, a little pinhole was found at the bottom of the chamber, and through that pinhole the germs got in. Here is a melon-infusion; and, in order to show you what would have occurred if the infusions had not been protected from the floating dust of the atmosphere, we have hung beside this case two tubes that have been exposed to the common air and have fallen into a state of utter rottenness. In this way, from the Jodrell Laboratory at Kew, we have had these cases returned with their infusions perfectly intact. Even in our infected atmosphere, when we subject our infusions to experimental conditions sufficiently stringent, we are able entirely to shut out contamination, and to show that spontaneous generation never occurs. When we get clear of our atmosphere altogether, this is a matter of perfect ease; and we find in Kew Gardens that Nature runs her normal course.

RELATIONS OF THE AIR TO OUR CLOTHING.[1]

By Dr. MAX VON PETTENKOFFER,

PROFESSOR OF HYGIENE AT THE UNIVERSITY OF MUNICH.

THE committee of the Albert Society has honored me by an invitation to give a few popular lectures at Dresden, on subjects of public hygiene. Let me state to you at once what I think of popular lectures in general.

What ought they to be, and what can we expect from them? I am not one of those who, in all their work and aim, look out directly for the practical use, for the return on the capital, immediate or prospective; but, on the other hand, I feel myself bound, in a certain degree, to inquire into the object of much that may appear to be either unprofitable or useless.

There is no doubt that *popular* lectures on *scientific* subjects will not impart really competent knowledge, and will not form experts.

[1] Abridged and translated by Augustus Hess, M. D., member of the Royal College of Physicians, London, etc.

Therefore it will be maintained by many that such lectures produce more evil than good, creating as they do, and augmenting, that dilettanteism from which our period is already suffering. In our schools also this dilettanteism is gaining such dimensions, that one might get thoroughly frightened at the immoderate expansion of young people's knowledge, were it not for its small depth, which lessens the danger, and for the fact that the forgetting keeps pace with the learning. Accept my open avowal, that I also am unable to invalidate the objection that *popular* lectures on *scientific* subjects are not able to impart a really competent knowledge, and do not form experts.

But I believe that this does not matter, and that they have no such purpose. They are neither an exhaustive, scientific, nor a practical instruction, but a scientific edification and elevation, which are to raise our minds and hearts, and to affect us like listening to good music—to a symphony, the purpose of which is certainly not to make musicians of all the listeners. It is sufficient to feel the harmony which lies in the nature of good music. There is harmony in all our knowing and doing, our aiming and striving, as far as there is *truth* in them, and fortunately the sense for perceiving this harmony is as widely spread among mankind as the sense for music. This harmony, which pervades every truth, ought to be brought home to the consciousness and feelings of everybody, so that the greatest number may rejoice and become interested in it, that we may approach new subjects, and perhaps make them our study, or that, at all events, knowledge and resulting sympathy may induce us to lend our help to those men whose profession and calling require them to enter more minutely and exactly into the subjects in question. In this respect popular lectures have a high and serious mission. It is their mission to create correct general ideas, to facilitate our grasp of them, to awaken and spread a certain love for different tasks of mankind and of the period, to form ties of friendship between things, ideas, and men. Sympathy and sacrifices cannot be expected or asked from us, if their objects are unknown to or badly understood by us.

For these reasons it is my desire to awaken your interest for some subjects relating to hygiene, and particularly to impress upon you most vividly how much in this respect remains to be done and created, a work we all ought to take our share in.

One of the incessant wants of man is air.

We want air mainly to nourish us and to keep us cool. The quantity of air inhaled and exhaled by an adult in twenty-four hours amounts on an average to about 360 cubic feet, or 2,000 gallons. What we take in and give out during twenty-four hours, in the shape of solid and liquid food, occupies on an average the space of $5\frac{1}{2}$ pints, which is equal to $\frac{1}{3000}$ of the volume of the air passing through our lungs. It will astonish you to hear, perhaps, for the first time that this amounts to 730,000 gallons in one year, and to be reminded of

that continuous work, which goes on day and night—a never-ceasing bellows-blowing, by which the organ of our life is kept in play. Of course, the quantity of air flowing round the surface of the human body is much greater than that. Do not object, that air is something so light that it need not be taken into account. It has some weight; water, certainly, is 770 times heavier, but our daily 2,000 gallons have for all that a weight of 25 pounds avoirdupois. Still, as it is not my intention to dwell here upon the subject of our oxygen-alimentation, I will to-day consider only the second use we make of the air, the cooling of our working machine.

You all know that life is bound up with chemical processes, kept in continual activity through the ingestion of solid and liquid food, and of oxygen from the air. One of the conditions for the normal performance of these processes is a definite temperature, above and below which they (although not brought to a standstill) go on differently—they leave off performing the functions of normal life—they lead to disease or death. With man this uniform temperature of his organs is one of the most essential conditions of his life. The blood of the negro living in the torrid zone of the equator is not by one-fifth degree warmer than that of the Esquimaux in the highest north at the coldest time of the year—it is always 99½° Fahr. The extremes of temperature under which human life exists are 95° to 104° Fahr. in the tropics, and 57° to 84° under freezing-point in the polar regions. There are even differences of 72° in the mean monthly temperatures of some countries, and yet the organs of man are everywhere of the same temperature.

By what means is man enabled to meet such colossal differences? What are his weapons for sustaining this gigantic struggle?

Let us look a little nearer into the absolute quantities of heat the living organism has to manage. The chemical processes going on in an adult person, within the space of twenty-four hours, produce about 12,000 caloric units. By caloric unit natural philosophy designates that quantity of heat which is necessary to raise the temperature of one pound avoirdupois of water by one degree of Fahrenheit.[1] By the heat produced by one person during one day about 660 gallons of water could be made warmer by nearly two degrees, or 7⅓ gallons could be heated from freezing to boiling point, from 32° to 212° Fahr.

Under certain conditions man produces more or less heat; for instance, according to the quantity of food he takes, or the degree of muscular exertion he undergoes, such deviations from the mean amounting at times to 50 per cent. of the whole quantity; but it is always the task of the body, and a strict condition for the maintenance of health, to keep the heat of the blood substantially the same, or at least within two degrees.

We have to look upon ourselves as warm and humid bodies placed

[1] Rankine's caloric units are used by the translator.

within a cooler atmosphere. Such bodies lose their heat in three different ways: 1. Radiation. 2. Evaporation. 3. Conduction. This triple arrangement is of great advantage for the heat-department of our organism, inasmuch as the existence of these different routes allows of a delicate regulation—that, for instance, which we lose in a given case by radiation can be made up by diminution of loss through the other routes, and *vice versa*. The losses by radiation and by conduction are the most constant under equal conditions, and evaporation of water is the principal means for equalizing differences resulting from varying production of heat or from difficulties of the two other routes. Allow me to illustrate this by drawing your attention to some every-day phenomena.

You arrive, for instance, in an hotel after a journey during a cold winter's day, and have at once a fire lit in your room. Let the fire be ever so bright, the thermometer even rise to a reassuring degree—you must stick to the fireplace; the room does not get warm. If you continue to live in the same room and have the fire kept in, it will by-and-by get comfortable even if the thermometer in the room should stand lower than on the first day, and you will think quite correctly that the room wanted time to get warmed through and through. Before that had taken place, the loss of heat by increased radiation into the incompletely warmed space made itself sensibly felt in the heating department of your body. Radiation is the stronger the greater the difference of temperature between the two bodies. Surrounded as you are in a room not only by air, say of 68° Fahr., but also by walls, furniture, etc., which stand, perhaps, at 38° to 40°, your body radiates its heat particularly toward these colder objects, till they also get warmer. For a room to be warm, it must get warmed with all which it contains.

Let us now look at the contrary case, when our loss by radiation is uncommonly limited; for instance, in a thronged room on a warm and moist day. You feel an oppressive heat, and scarcely trust the thermometer, which marks only 68°, perhaps your favorite temperature. Quite correctly, you accuse the throng of people, and retire into an adjoining room, where you find the air delicious, and seem to receive new life; there, again, the thermometer is suspected by you, as it is scarcely different from its colleague inside; and if the air in the two rooms were to be examined eudiometrically, the difference would be so small as to leave unexplained the difference in your sensations. What, then, causes this difference? It is the suppression of your lateral radiation of heat, when you are in the midst of other equally warm bodies; your receipts and expenditure by radiation cover each other, and the cooling of the individual limits itself to the two other routes, conduction by the air moving round him, and evaporation of water from his surface. On such occasions the pores of your skin pour forth a quantity of water, and, at the same time, you

instinctively try to increase the movement of the air—that means, its quantity in proportion to your surface; you want to increase your loss by conduction, and, if possible, by evaporation, and take to fanning, in order to facilitate the departure of your rising heat by the two open routes.

The loss by radiation can be very considerable under certain circumstances; 50 per cent. of the whole quantity of heat generally going that way, it is obvious that radiation deserves our full consideration. Particularly, an unequal radiation may be very injurious, such as takes place when a person is sitting or lying near a cold wall which is not covered by some bad heat-conductor, or near a window, etc.

On school-forms, the exposed sides of the first and last pupils are always more cooled than the sides directed toward their neighbors. In this respect there are numbers of practical points which are far from being sufficiently taken into consideration.

Let us now consider some instances in which the abstraction of heat by evaporation is predominant, or preëminently felt. The best known is that experiment by which one tries to learn the direction of the wind when the air appears calm and the sky cloudless. The moistened forefinger feels colder on that side which looks toward the wind, because more evaporation takes place there. The experiment does not succeed so well when the air is moist, because the moisture in the air prevents further reception of moisture by it; in our case, preventing the evaporation from the moistened finger.

Our organism acts similarly in all cases where there is an increased production of heat in our body, or where less heat is sent away by the two other routes. It has the power of dilating or narrowing the small blood-vessels in our skin and internal organs. The blood-vessel nerves which govern this motion are not subject to our will, but liable to be excited by external causes. When a person blushes, he gives off heat, because more blood rushes into the dilated blood-vessels of his cheeks and periphery generally, and more heat leaves the body. Under similar circumstances the whole surface of our body becomes fuller of blood and warmer, there is more heat to radiate and to be conducted away, and to be consumed by increased evaporation of the watery part of the blood.

The great value of evaporation for the cooling of our body can be estimated by calculating that as little as fifteen drops of water requires $2\frac{1}{4}$ caloric units to be changed into vapor.

We have at Munich a great apparatus for studying the process of respiration. It was given by the late King of Bavaria, Maximilian II., to the hygienic department of the university. Prof. Voit and myself have, by aid of this apparatus, investigated the quantity of water evaporated by men and animals during twenty-four hours. The constant result was that, under other similar circumstances, the quantity of evaporated water always rose in proportion to an increased meta-

morphosis of tissue, whether this increase was the consequence of increased nutrition, or of muscular exertion. We have experimented upon men at rest and at work, and we have found that on a day of rest they usually evaporated through lungs and skin about two pounds only during twenty-four hours, and on a day of hard work $4\frac{1}{4}$ pounds of water. In the first instance, about 2,016 caloric units, in the second, 4,480 had to leave the body in consequence of evaporation.

This explains to you how it can be that even with the hardest work our blood will not become warmer, but sometimes even cooler. The last observation has been made quite recently in mountaineering expeditions. Prof. Lortet, of Lyons, found, when he made an ascent of Mont Blanc, that the temperature in his mouth and armpit was less than normal, and became normal only when he was at rest. On such high mountains the lessened pressure of the atmosphere favors the peripheric circulation, there is a rush of water to the surface, and its evaporation takes place more readily, and increases with the altitude. At great heights persons in a balloon constantly complain of great dryness in the mouth.

Profs. Voit, Recknagel, and myself, are just now occupied in investigating the economy of animal heat, and we have found that after six hours' hard work the person leaves the apparatus in a cooler condition than when he went in, or after he had been at rest in the apparatus for the same space of time. Of course, the ventilation of the apparatus must work well, and send per hour about 11,100 gallons or 1,800 cubic feet of air through the chamber, else less water and less heat depart by evaporation.

You see what powerful means of cooling our body we have in the increase of our peripheric circulation, and consequent evaporation, at a time when the other routes are not open sufficiently—but you see also how dangerous this means can become, if it is employed at a time when considerable quantities of heat depart on the other routes. If, heated and damp, you enter suddenly a cold space, where radiation increases at once, and a good deal of heat is also yielded by conduction to the cold air, you are in great danger of contracting an illness by the abnormal losses of heat, and the violent and sudden changes in the circulation. But if you undergo such changes slowly and gently, the three routes open themselves harmoniously. Our organism is a faithful and clever servant, who helps himself and his master, provided he is not hurried and ill-treated. When I come to speak of ventilation, I shall not forget to tell you of currents of air, called draughts.

The third route, that of conduction, by which we give up heat to the air, is also of great importance, and must in some circumstances replace the two others to a considerable degree. As long as our body is warmer than the surrounding air, this air gets warmer at every point of contact with our body, but at the same time lighter, and as

such it is displaced by colder and heavier air, which in its turn gets warmer and lighter, and so on.

Each person standing in the still air of a room causes in this way an ascending current of air, just like a heated stove. A very sensitive anemometer, placed between coat and waistcoat, shows the existence of this current, which is strong enough to set the little wings of the instrument in play. The air in this room appears quite still, and yet it is in thousand-fold motion and ceaseless restlessness; but, happily, our nerves are not aware of this, just as a short-sighted person may deny the existence of some object, till his eyes get the assistance of a glass. Whoever of you would be able to feel or see all the movements of the air in this room would probably not be able to stand it. A correct idea may be formed about it by the action of smelling substances. If, for instance, an escape of gas were to take place in a remote corner of this large room, you would become aware of it almost immediately all over the room. Our nerves are happily so organized that they begin to feel the motion of the air only when it amounts to about $3\frac{1}{4}$ feet per second.

You may have some doubt about this ignorance of your nerves, because the proof lies not in our immediate perception, but in conclusions from other observations; but you may easily convince yourself that it is so. It is the same thing whether you move your hand at a certain rate through a still air, or whether air moves at the same rate round your hand. You will find that you do not feel anything, no resistance, no coolness, if you move your hand at less than 19 inches per second.

I take this opportunity to draw your attention at once to the average movement of air out-of-doors, a subject very imperfectly known to most people, but which you must understand well in order to have a correct idea of the real difference between being in a room and in the open air. The velocity of the air is measured by an instrument called an anemometer, a description of which you can easily get at. In our temperate climate this velocity amounts on an average to about 10 feet per second. This would make about 7 miles per hour. Imagine a frame about the height and width of a human body; let us say it measures about 6 feet by $1\frac{1}{2}$, or 9 square feet. If you multiply this by the average velocity of the air, you will find that in one second 90 cubic feet, in one minute 5,400 cubic feet, in one hour 324,000 cubic feet of air flow over one person in the open. I shall come back again to these numbers when we have to consider the subject of the ventilation of dwellings, but you will already understand that it is not too much if 2,100 cubic feet of new air per hour and per bed are considered necessary in the ventilating arrangements of hospitals, etc. This quantity, which appears large, is after all only about $\frac{1}{160}$ of the quantity of air which comes in contact with a person in the open at the above stated average velocity of the air.

You see, therefore, that we give off more heat by conduction in the open air than in a room, and in the latter proportionately more by radiation and evaporation.

The power of conduction is best appreciated when we change the air for some other fluid medium, which is a better conductor than air, and more capable of absorbing heat, I mean water. In air of a few degrees of heat, we can feel pretty comfortable with moderately warm clothes; but, if with the same amount of clothing we were to get into water of the same temperature, we should feel painfully cold, and should probably be frozen to death in a few hours, although our loss by evaporation would have ceased entirely, and that by radiation nearly so. In hot climates, therefore, a daily bath is of great service for the necessary cooling of our body, even if the water is not cooler than the atmosphere.

In the air also the loss of heat by conduction is the greater the lower the temperature, and the greater the velocity of the air which flows around us. This explains on the one side why it appears superfluous in a calm and cool air to make use of a fan, while this expedient acts so beneficially at higher temperatures; and on the other why, as a rule, a warm air in motion appears much cooler than a calm one of equal temperature. Think of the sultriness before a thunder-storm, as long as the air is at rest, and how differently we feel as soon as the first wind rises. The air is not yet cooler, not less saturated with vapor than before, and still it deprives us of so much more heat that we deem it less sultry, even cool, only because it travels over us faster.

When we fan ourselves in a hot and damp air, the same thing takes place—then, also, a greater amount of air passes over us in a given time than if we leave the air to its own motions. The fan changes nothing in the temperature and moistness of the air, it only increases its velocity, and in consequence the abstraction of heat, and thus affords us coolness chiefly on the uncovered or only slightly covered parts of our bodies; therefore, ladies have more reason for using it than the stronger sex.

As long as the air is our surrounding medium, an increased evaporation associates itself with the increased loss by conduction, at least as long as the circulation of the blood in the skin remains active and the air is not saturated with moisture. The fan scarcely ever cools by increased conduction alone, but also by increased evaporation. Therefore, fanning with dry air is much more cooling than fanning with a moist air of equal temperature. We all know how much quicker wet roads and wet clothes dry when there is a good wind. However rapid the motion of moist air may be, it does not dry. When our body is bathed in perspiration the fuller condition of the skin occasions an increased transfer of heat from the dilated blood-vessels to the surrounding air by conduction, but generally also by evaporation.

In southern climes, at the hottest and moist time of the year, when

the body cannot lose much heat by radiation toward colder objects, when the temperature of the air approaches and even surpasses at times that of our blood, the European often feels the heat to suffocation, and besides the use of the bath he has no other practical remedy than the fan and the shade.

In the shade the air is not only cooler, but also more in motion. The difference of temperature between a place sheltered from the rays of the sun and a neighboring one exposed to them, produces a motion, a current, because bodies of air of unequal temperature are also of unequal weight. They are not in equilibrium, and seek to reëstablish it by motion. Any one may easily convince himself thereof who, on a hot day with calm air, walks alternately over places exposed to the sun and sheltered from it. As soon as he comes into the shade of a cloud, a house, or a tree, he feels at once a soft wind rising. The shade not only protects us against the direct solar rays, but it increases also the ventilation of the shady place.

The fan acts on the same principle. The *pankha* in the bungalow, by increased conduction and evaporation, keeps the blood of the European at its normal temperature of $99\frac{1}{2}°$. When the temperature of the air rises to 140°, when the walls of the house or bungalow are no longer cool enough to provoke radiation from the heated human body, man is reduced to cooling by evaporation. It greatly depends upon the state of dryness of the air how far he succeeds. The drier the hot air is, the better is it able to withdraw water from the skin, from the respiratory organs, from the wetted floors, and consequently the more heat from the human body. The moister it is the less it is able to act thus.

In order to give you an idea of the quantitative differences in play, we will consider the losses of heat by respiration as they take place at different temperatures and different conditions of moisture of the air we draw in. In twenty-four hours the quantity of this air is on an average 2,000 gallons. It has been calculated that by the process of respiration a person loses 1,172 caloric units when the air is at 32° and quite dry, 1,116 when it is half saturated by water, 1,060 when it is completely so. The difference between the two extremes is only a small percentage of the whole loss. But, when the temperature is 86°, the above numbers would be respectively 1,096, 760, and 420.

A comparison of the losses of heat by the respiration of an absolutely dry and an absolutely saturated air at 32° and 86° Fahr. is highly instructive. We lose:

at 32° and dry	1,172 caloric units.
" 86° " "	1,096
difference only	76
at 32° and saturated	1,060
" 86° " "	420
difference as much as	640 caloric units.

The different state of dryness of the air appears thus to be of a greater moment than the difference of temperature, and this is the reason why our sensations do not always coincide with the thermometer. You readily understand how much more difficult it is to manage one's heat-household in a hot than in a cold climate. Our means for warming ourselves are better than those for carrying off our heat. Therefore the European race has a hard fight under the equator. The working power of the body depends on a certain amount of consumption, by which a certain amount of heat is necessarily created, which has to leave the body in a regular way. The Hindoo who has to draw the European's *pankha*, bears the heat better in proportion as he takes less food and creates less heat in himself, but then his working-power is also quite proportionate to the total of his consumption.

The European's struggle in a hot climate and his dangers of degeneracy will remain the same as long as he has no better means of cooling himself by some or all of the known three routes. Houses with thick stone-walls are tolerably efficacious. These walls rarely get warmer than the average temperature of the year. They cool the air which comes into the house, and act on the inmates in the way we have seen when speaking of the room which is not warmed through. A good means would be some contrivance by which the air in the house could be deprived of its water.

I could not help inflicting upon you this rather long introduction, nor could I possibly abbreviate it, as, without the little knowledge which I have tried to impart to you about the cooling of the human body, you would not be enabled to obtain a proper insight into the functions of our clothing and our dwellings. Therefore I believe myself to have had a good claim on your patience and indulgence.

One of man's principal defensive weapons in his struggle for existence is his clothing. The place it takes in the history of civilization and its connection with physiology are not often thought of. People speak about it generally from a moral and æsthetic point of view, but the main purpose of clothing is seldom approached in conversation—I mean the purely hygienic one. I deem this to be a misfortune, because this forgetting of the chief point has subjected mankind to the rule of small and frivolous considerations, and the manners and fashions of the period get frequently the better of the hygienic fitness of the clothing. Morality and beauty do not depend on dress. They cannot be created or preserved by it. These great qualities could even exist without it, but the human body as it is could not, or only barely and imperfectly, exist in our climate without the protection of clothing, which is more indispensable for our health than for our beauty and morality.

So manifold are the changes brought about in our system by clothing ourselves, that I am unable to give you more than some incomplete parts of the subject.

When I cover one part of my body I change the degree of abstraction of heat by all three routes known to you, but without obstructing any one of them entirely.

To speak in the first instance of radiation, it will be clear to you that our surface is prevented from radiating heat directly toward the colder objects in our neighborhood, and that it can only radiate toward the covering materials, which receive this heat. By the laws of conduction and radiation the heat, which has radiated from the body into the clothes, has to travel through them by radiation and conduction, till, arrived at their outer surface, it can radiate thence toward colder objects, just as it would from the naked surface of the body. Thus by our clothes we keep the heat radiating from us somewhat longer in the immediate neighborhood of our surface. The lightest covering even makes itself perceptible by impeding radiation, the thinnest veil keeps warm in some degree. It is just the same with the earth itself. On a calm, clear night the earth's surface becomes so chilled by radiation into the colder space, that the moisture of the air precipitates itself on it as dew, and at times as hoar-frost, and even as ice, just as the moisture in a warm room does on a window-pane cooled from the outside; but, when a veil of clouds overhangs the earth during the night, the earth never cools itself so much as to allow of any dew forming.

There are substances, called diathermal, which allow the rays of heat to go straight through them without any absorption, for instance, the crystals of common salt, but all the materials of our clothes are such as absorb the rays of heat which come to them from one side, and only part with them after they have reached the outer surface. The transit of heat through what we may call our artificial surface depends essentially on the conductive power of the material and its thickness, i. e., on the length of time and way which the heat has to go through in order to travel from our surface to the outer surface of the garment.

Thus the whole immediate neighborhood of our body is continually warmed in an even degree by our radiating heat, and our sensitive skin is spared the numerous disagreeable or injurious effects of a rapidly-changing temperature.

The heat does not remain in our clothes, it is continually on an outward move, faster or slower, and, to a certain degree, also warms the stratum of air between our clothing and our skin, so rich in nerves and blood-vessels. This air, as we shall see presently, continually changes, and must change if we are to feel comfortable. In the cold of winter, and in the open air, we lose our bodily heat out of our well-selected garments without any sensation of cold, only because we have removed the place of exchange between the temperature of our warm blood and the cold winter air from our sensitive surface to a substance without life and sensation; instead of our skin, our dress

feels the cold. It is the same with the hair of animals, and the feathers of birds, they are also without nerves.

In proportion as our heat-losses increase, while the creation of heat in our interior remains about the same, we feel the necessity of diminishing the rate at which the heat leaves our immediate neighborhood. This kind of regulation is somewhat taken care of involuntarily even by the naked body. In consequence of the cold, the nerves which act on the calibre of the blood-vessels of our surface contract them, and lessen the quantity of blood in them, so that less heat comes to the surface, and we need not be afraid of becoming also inwardly colder if we feel cold, even very cold.

The sensation of cold on the skin does not necessarily give the measure of our internal temperature. In the cold stage of ague, for instance, the temperature of the internal organs rises considerably, while by a kind of spasmodic contraction of the superficial blood-vessels the flow of heat toward the skin is less than normal. The above-mentioned regulation of heat-loss by the capillary system of our skin is not all-sufficient either in point of time or degree. The cold may be too strong, and the regulator get overworked and paralyzed, so that additional clothing is required to delay the departure of our heat, and to spare the nerves of the blood-vessels. We help ourselves by additional clothing, and the underlying article of clothing stands in the same relation to the outer one as the skin to its first covering. From this point of view you have to consider the sequence of shirt, under-clothing, coat, overcoat, etc., etc., an arrangement by which we save the vasomotor nerves the greater part of their work.

It is an open question, which the incompleteness of our hygienic knowledge prevents us from answering quite satisfactorily, how far we ought to hand over the regulation of our heat-loss to our dress, or how far we should go in deputing it to our organism, and its capability of transferring more or less heat from the centres to the surface of our bodies. This self-help of the organism and the readiness for it resulting from frequent exercise of this function are generally called hardening one's self; the contrary, making one's self tender. The former we can never quite dispense with, but I believe that too high a value is sometimes put and too large claims made on it. One ought to possess the capability and the readiness, but not to make use of them continually.

All human aim must be to obtain the greatest effect at the smallest expense. We ought to choose those means which attain the end without exhausting our power, which should be preserved for higher purposes. These principles ought to guide us in approaching the question. It is not only superfluous, but positively injurious, to use one's self up.

I believe that it is now evident to you that a part of the heat of our body radiates from the surface of our clothing; but we must now consider whether this radiation does not vary according to the nature, quality, or color, of the material. Experiments which have been

made by Dr. Krieger on wool, wash-leather, silk, cotton, linen, and India-rubber, have not shown any important difference. Krieger covered cylinders made of tin and filled with warm water with different and differently-arranged materials, and noted the decrease of temperature in stated periods. He used layers of two different materials, but it made no great difference what the outer layer was. Still, I will mention that silk and cotton allowed more heat to radiate than wool. The color also of the material has been shown to have no great influence on the radiation of heat, which remains the same, whether we have a black or a white garment on.

But it is quite another case when we receive luminous heat, rays of heat proceeding from luminous bodies, such as the sun, or some flame; then differences result, which certainly are not very great with different materials of the same color, but become great indeed when the colors are different. For white textures the following proportions are found:

When cotton received	100
Linen received	98
Flannel "	102
Silk "	108

With shirtings of different colors the proportions were:

White	100
Pale straw-color	102
Dark yellow	140
Light green	155
Dark green	168
Turkish red	165
Light blue	198
Black	208

Of course, you all know by experience that, when dressed in black, you feel much hotter in the sun than when dressed in white. It is remarkable that, pale straw excepted, each color heightens considerably the absorption of luminous heat-rays, and that blue does so nearly as much as black. But, as soon as we are in the shade, the differences nearly vanish.

If we continue to consider our loss of heat by radiation through and from our clothing (omitting for the present conduction and evaporation), we come at once to the practical question, how much this loss is retarded by interposing several strata of material between our surface and the air, or in fact to the question about the heat-conducting power of materials and textures. Very few experiments have been made in this respect. We know, with respect to this point, the properties of metals, of minerals, of chemical compounds, but not of wool, linen, or leather. This shows, by-the-by, how little hygiene has been treated until now in an exact and scientific way. We talk in a general way about the use of garments as bad conductors of heat,

but the few experiments known to me entirely run counter to our accepted ideas.

Krieger experimented on cylinders filled with warm water, by surrounding them tightly with single or double textures. As the loss by radiation is the same in both cases, any difference must result from difference of conductive power in the coverings of the cylinders; but the results were, for the most part, surprisingly small. The following numbers represent the proportions of loss of heat through double tight-fitting coverings in comparison to single ones; the losses through the single ones being taken as 100, they were, through—

Double thin silk	97
" Gutta-percha	96
" Shirtings	95
" Fine linen	95
" Stout silk	94
" Thick home-spun linen	91
" Chamois-leather	88–90
" Flannel	86
" Summer buckskin	88
" Winter buckskin	74–84
" Double stuffs	69–75

The whole question is certainly not exhausted by these experiments, but one thing becomes evident by them, that it is not the substance and its weight, but the texture and the volume, which are the principal causes of the difference. Thin and stout silks, fine and stout linen, are nearly equal in substance, and equal sizes of them are not so very different in weight; it is their different heat-conducting power which causes the difference of the loss, and this is, even through two layers of them, not as much as ten per cent. smaller than through a single one.

By other experiments one can demonstrate that, by changing the shape and volume of the same substance, great changes of heat-loss can be produced, although the substance and its weight remain the same. If you cover the tin cylinder, previously filled with warm water, with common wadding, and observe the falling of the immersed thermometer, you will be astonished to see how rapidly the fall goes on, as soon as you compress the wadding firmly and diminish its volume: the outward flow of the heat increases by forty per cent.. The same, you know, is the case, when a wadded garment is worn out; the quantity of the wadding is the same, but its volume and its elasticity have undergone a change, and you will find it considerably less protecting.

This observation leads to another instructive experiment, relating to the influence of double layers of material. If the first layer only is tightly drawn over the warm cylinder, and a free space of one-third to one-half an inch between it and the second, which may be compared to a comfortably-fitting garment, the second layer very considerably lessens the outward flow of the heat. The amount due to conduction

being deducted, the impediment by the second layer is about the same for different materials, but very considerable for each of them:

For Linen	32 %
" Shirting	33 "
" Silk	32 "
" Flannel	29 "
" Wash-leather	30 "
" Gutta-percha sheeting	36 "

From this follows the practical truth, that we can produce a very different effect on our body by the same number of clothes, according to the tightness and looseness in the make. Just call to mind tight shoes and gloves in winter-time!

This fact leads to a series of other facts, which contain the explanation why wadding, as long as it is loose and elastic, keeps you warmer than when it is once flattened. This is the air contained within the clothes.

One generally considers clothing as an apparatus for keeping the air from us. This conception is utterly erroneous; quite the reverse, we can bear no garments which do not allow of a continual ventilation of our surface. Just those textures which are most permeable to the air keep us warmest. I have examined different materials for their permeability to air, which can be easily ascertained. One closes a series of perfectly equal glass tubes with different textures, and observes how much air passes through the clothing substances at the same pressure during the same time. Taking the quantity of air passing through flannel as 100—

Linen allowed	58
Silk "	40
Buckskin "	58
Kid "	1
Chamois "	51 parts of air

to pass through them.

If our clothing kept us warm in proportion to its power of excluding the air from our body, kid would keep us a hundred times, and chamois warmer by one-half than flannel, and so on, while every one knows by experience that it is quite the reverse.

If there are several layers of the same material, ventilation loses but very little at the second layer, because the velocity of the air in its passage through the first layer remains about the same on its further progress, the following layers being like a continuation of the preceding ones, as if they were tubes of the same calibre, retarding the original velocity of a fluid by the amount only of unavoidable friction.

Thus, a current of air travels incessantly through our clothing. Its force, as in ventilation generally, depends on the size of the openings, the difference between the outside and inside temperature, and

the velocity of the surrounding air. We need not be anxious to make our clothes prevent the access of air to our skin; they have only to regulate and moderate it to such a degree that our nerves may not feel the air as something in motion. This degree is far from immobility. When in the open air we believe it to be quite calm, there is still a velocity in it of at least one foot and a half per second, or about one mile per hour, as you heard before.

Our clothing not only renders the air still around us, but it also regulates its temperature by the heat which leaves our body; we heat our garments, and they continually heat the air passing through the meshes and pores of the texture. We may compare our clothing to a calorifer or stove, warmed by the heat emanating from our body's engine for the purpose of warming the air round our surface.

We do not feel the loss of heat which our clothing undergoes as we should if the air were to strike our surface without having been previously prepared by our dress; the differences of temperature balance themselves within the material we are clothed in, and of which the ends of our cutaneous nerves form no part. Inside our dress we carry the air of the South wherever we may be. Its temperature averages about 75° to 94° Fahr. We live in our dress like an unclothed tribe in a paradisian country, where the air is constantly calm and the temperature 75° to 94°. It will be easily understood now why rough, loose textures keep us so warm, while newly-carded cotton-wool does so more than when old and compressed; why tissues of fine fibres and threads make the best material. Fur, of which you know so well the properties, consists of hair and skin. Chemically speaking, there is not much difference between skin and hair. In fur the weight or body of the skin is much greater than that of the hair, and still it is essentially the light hair to which the fur owes its warming properties.

There are some interesting experiments on this point. Krieger observed the flow of heat after covering his cylinders with unshorn and shorn fur. Putting down the loss of heat through the entire fur as 100, he found that it rose to 190 when the same piece of fur was used shorn. A dried skin, you know, is always somewhat porous. When he altered this by giving it a coat of linseed-oil varnish, the loss of heat rose to 258; and, when he took a solution of gum-arabic instead, it rose even to 296.

It has been proved that the living organism, in parting with its heat by radiation and conduction, behaves just like a tin cylinder filled with warm water. It is a yet older observation that furred animals, such as dogs, rabbits, etc., cannot live when they are shorn and their skin varnished or oiled. One used to explain their death by the suppression of the evaporation from their skin, but it can be proved that even in a comfortably-warm room these animals literally freeze to death. Krieger sheared a rabbit, after having noted its temperature

and frequency of respiration; they were 102° and 100 per minute. He did not use any varnish, to avoid any possible suppression of evaporation from the skin, but enveloped the shorn animal in a wet cloth. The temperature of the room being at 66°, the animal lost so much heat that, after five hours, its interior temperature had fallen to 75°, and its respiration to 50 per minute.

A fur is so arranged that its fine hair, projecting into the air, intercepts all the heat, which flows from the surface by radiation and conduction, and distributes this heat through the air, which circulates between the single hair-cylinders; the finer the hair of the fur, the more of the outgoing heat is taken up by the air, which, however cold the temperature may be, reaches the nerves of the skin as a warmed air. Furred animals, in winter, when touched superficially, give a very cold sensation; it is only near the skin that their hair feels warm. In severe cold, certainly little of our animal heat comes as far as the points of the hair, from which it would radiate or be conducted into the air; the current of air in the fur cools the hair from its point toward its roots, and a severer cold penetrates only a little farther into the fur, without necessarily reaching the skin of the same. This takes place only when the temperature is uncommonly low, and the air in violent motion. Travelers in high latitudes all agree that extreme degrees of cold can be borne very well when the air is calm, but scarcely so when there is a brisk wind.

This tends to show that in very severe cold the outflow of heat, by the skin into the air contained in the fur or within the dress, takes place through one route only—that of conduction; when a fur is worn, no heat comes to the surface for radiation, as soon as the points of the hair have the temperature of the surrounding air. Evaporation also sinks to a minimum, because at 68° Fahr. under freezing-point all formation of aqueous vapor already ceases, and nearly all the heat in the fur and the dress is employed to heat the arriving air, whose velocity increases according to the difference of temperature. In a well-furred animal the changes of temperature in the surrounding air only change, if I may say so, the latitudes of the cold and warm zones in the fur; the place where the temperature of the body and the air equalize each other moves between the roots and points of the hair, and for this reason such a well-furred animal is not warmer in summer than in winter. Its blood keeps always at the same temperature, because in summer a great part of its heat leaves at the points only of the hair by radiation and conduction, while in winter the heat departs already near the roots of the hair.

Air-proof fabrics ought to have only a very limited use. In India-rubber or gutta-percha textures we feel highly uncomfortable when we have to undergo much exercise, or have to give off more heat than usual. They become inconvenient, not because they stop the change of air entirely—which they cannot do in fact, on account of the neces-

sary openings in them—but only because they limit the universal exchange of air in the underlying garments. For protection against the wet from without they are well suited, but they produce another wet on our skin by impeding evaporation. They may be used in wet weather, when accompanied with cold or wind, but never, though wet, when it is warm or calm.

Finally, I have to draw your attention to the relations which the materials of our clothes have to water, by which their functions are considerably altered. They are all hygroscopic; that means that they condense from the atmosphere a certain amount of water. This hygroscopic property, very different in different bodies, increases with the decrease in the temperature of the air, so that all of them condense more water at freezing-point than at higher temperatures. Partly, also, the relative moisture of the air is of some influence, so that at 68° the hygroscopic body absorbs more water from an air nearly saturated than from a less moist air. As yet we do not know much about our clothing materials in this respect. I have made some preliminary researches, and have found unexpectedly great differences.

I took two equal pieces of flannel and of linen, as representatives of the two most important fabrics made of vegetable and animal fibres, and dried them at 212°, a temperature at which they lose all their hygroscopic water. I put them into well-closed boxes of known weight, and noted the weight of the two together. They were then exposed to the air in places of different temperature, and from time to time put back into the tin boxes, and the weights taken again. By this method it was not difficult to ascertain the relative quantities of hygroscopic water which the flannel and the linen had absorbed. These quantities are tabulated below, as they resulted from different localities, temperatures, and lengths of time, the weight of the linen and flannel being 1,000 grammes each:

OBSERVATIONS	LOCALITY.	TEMPERATURE.	TIME.	HYGROSCOPIC WATER IN	
				Linen.	Flannel.
1	Cellar.	37.58° Fahr.	12 hours.	77	157
2	Lecture-room.	34.16	" "	74	143
3	Room.	64.25	" "	41	75
4	Laboratory.	53.96	" "	63	105
5	Cellar.	39.92	" "	111	175
6	Lecture-room.	40.1	4 hours.	93	160
7	"	40.1	3 "	91	148
8	"	41.9	15 "	85	146
9	Room.	69.8	10 minutes.	73	113
10	"	69.8	" "	52	96
11	"	70.7	" "	45	87
12	"	70.7	" "	43	82
13	"	68.9	15 "	42	78
14	"	68	" "	42	77
15	"	64.25	30 "	41	75
16	"	62.6	1 hour.	48	76
17	"	61.7	2 hours.	45	77
18	"	59.9	..	46	78

What most strikes one is the invariably greater hygroscopic power of wool than of linen; the maxima and minima of flannel and linen being respectively 175 and 111, 75 and 41.

Observations 5 to 8 show that linen changes the quantity of its hygroscopic water at a proportionately quicker rate than flannel. The two pieces were for twelve hours in the cellar, when linen absorbed 111, flannel 175; immediately after, for four hours, in a cold place, where linen lost 18 per 1,000 of its absolutely smaller amount of water, while the flannel lost only 15 per 1,000; but during the next three hours linen lost only 2, but flannel 12 per 1,000.

When (Obss. 9 tó 15) the pieces had come from the cold lecture-room into a warmed room, linen again ceased giving off water at a much quicker rate than flannel.

The accelerated rate, only in an opposite direction, took place again (Obss. 15 to 18) when the temperature in the room sunk from 65° to 59°.

All bodies become more hygroscopic with a sinking temperature, but the absorption of water and increase of weight, as well as the contrary process, take place proportionately quicker with linen than with flannel.

The more the air in any material is displaced by water, the less it keeps us warm, the quicker it conducts the heat; hence the frequent injury resulting from wet clothes, and the striking discomfort produced by a damp cold. You all know how comfortable we can feel in a walk, when the air is cold and dry, and how differently we feel when it is damp, although not colder. Then our clothes also get much damper, and conduct more of our heat away.

This is not to be underrated. We have seen in the table that 1,000 parts of flannel took up in the cellar 157 parts of water. Take the weight of a whole woolen clothing as ten pounds, and you see that it may absorb one and a half pound of hygroscopic water, which requires about 1,680 caloric units from our body to be evaporated.

Linen and flannel bear the same relation toward water they are wetted with as toward their hygroscopic water. Linen is quickly wetted and soaked, wool more slowly, but linen cannot take up the same quantity. Spilled water has certainly taught you this many times, when you wanted to take it up. It is the same in evaporation, which is also much quicker from linen. Two equal pieces of linen and flannel, weighing each 1,000 grammes, put into water and wrung out till they no longer yield a drop of water, keep back respectively 740 and 913 per 1,000.

But a much greater difference exists in the intensity of evaporation from wet linen and from wet flannel, during equal periods, in a heated room.

OBSERVATIONS.	TEMPERATURE.	MINUTES.	WATER TO 1,000 GRAMMES OF	
			Linen.	Flannel.
1	70° Fahr.	..	740	913
2	68	15	521	701
3	68	30	380	603
4	67	30	229	457
5	66	30	99	309
6	66	30	55	194

It is easy to see from this table how much quicker linen works than wool in every direction.

During the first 75 minutes there evaporated from 1,000 parts of linen 511, from 1,000 parts of flannel 456 water; afterward the reverse took place: in the following 30 minutes 130 evaporated from linen, 148 from flannel, and in the last 30 minutes only 44 per 1,000 from linen, but 115 from flannel.

It is also evident how much more evenly the drying proceeds in wool: in the first 15 of the whole 135 minutes 219 evaporated from linen, in the last 15 minutes 28 per 1,000, while with wool it was respectively 212 and 97 per 1,000. I must not forget to mention that all these experiments were made with pieces of nearly equal size and shape.

It is self-evident that all textures lose their permeability to the air in proportion to their state of humidity, the water partly at least obstructing the pores. Coarser stuffs with larger pores will keep their permeability longer; if the pores are equal, the difference in the adhesion of the water to the substances will come into play. Linen, cotton, and silk are very different in this respect from sheep's-wool. The former become very quickly air-tight by wetting, the latter scarcely so, or only after a longer soaking. Soldiers can tell how damp and vaporous the air becomes under a wet tent, and how quickly the tent becomes airy when it begins to dry.

As the porosity of all fabrics depends chiefly on the elasticity of the fibres of their material, it must be of great importance how far that elasticity keeps under wet and dry. There, again, wool stands apart; its fibres do not lose much elasticity when they get wet: it is not so with other fibres. Wet linen and silk are just like Krieger's shorn fur, when it was coated with varnish or gum-arabic. The greater facility of catching cold in wet linen or silk than in wet wool is in exact proportion to the greater facility with which water expels the air contained in their fibres. Many of you may have learned a lesson from a wet linen or cotton and a wet woolen sock.

On the other hand, there is an advantage in these materials if we want to keep ourselves cool and dry. By means of them we part with heat and moisture from our surface much quicker, and hand them over to other layers for further removal.

To be quite methodical I ought now to treat of the different parts

of our clothing and of the fitness of different materials for special purposes. But, to say the truth, Science has not yet done much in this direction.

There is still one of our garments to be considered which generally is not regarded as such. I mean the bed—that piece of clothing in which we spend such a great part of our time. It is equally indispensable to the sick and to the healthy, and at all times it was considered as a sign of bitterest want if a man had no place to lay his head.

The bed is not only a place of rest, it is especially our sleeping-garment, and has often to make up for privations endured during the day and the day's work, and to give us strength for to-morrow. You know all the different substances and materials used for it. They are the same as our garments are made from. Like them, the bed must be airy and warm at the same time. We warm the bed by our body just as we warm our clothes, and the bed warms the air which is continually flowing through it from below upward. The regulating strata must be more powerful in their action than in our day-clothes, because during rest and sleep the metamorphosis of our tissues and resulting heat become less, and because in an horizontal position we lose more heat by an ascending current of air than in a vertical position, where the warm ascending current is in more complete and longer contact with our upright body.

The warmth of the bed sustains the circulation in our surface to a certain degree for the benefit of our internal organs at a time when our production of heat is at the lowest ebb. Hence the importance of the bed for our heat and blood economy. Several days without rest in a bed not only make us sensible of a deficiency in the recruiting of our strength, but very often produce quite noticeable perturbations in our bodily economy which the bed would have protected us from.

I wish, therefore, to impress upon you that your charitable exertions for the poor may become extended to the bed, that kind of garment which can make up to a great degree for other lamentable deficiencies, as in food, dwellings, clothing, toward which you are in the habit of directing your efforts.

I am quite aware that I have anything but exhausted the subject of the functions of our clothes, but still I believe that I have directed your attention to such essential points as to convince you of the importance which a scientific consideration of the subject possesses in the interest of the heat-economy of the human body.

As our health is so intimately connected with this economy, a better insight into the laws and proceedings of the same must in the end turn out profitable to health in general.

Thus we have learned in our last glorious war how important it is to provide well for the soldiers' clothing, and that a few days' want

of provisions is less injurious to the health of the soldier than perturbations of heat-economy through want of suitable pieces of clothing. Our clothes are weapons with which civilized man fights against the atmosphere as far as it is inimical, the means by which he subjugates this his element. It lies in our nature, in our instinct, in our self-respect, to have good clothes, which ought to be also pleasing to the eye; but we ought to become more conscious of their purpose. Ornament must be the minor consideration, and the tailor ought not to hold his scissors as a sceptre over the hygienic purposes of all dress.

Our period strives after novelty in all directions, also after new forms and styles in dress, architecture, and so on; but nothing new will be created with our old points of view remaining. New points of view can only be gained by new and increased insight into the functions of the dress and the house. This function must determine the form, and will not be ascertained without theoretical study. It was not till we had mastered the theory of the overshot and undershot water-wheel that the turbine could be invented.

The influence of theory on practical development is much greater than is usually supposed and conceded. The discovery and settlement of the laws of mechanics had to precede their application to engines, railways, steamboats, and so on. There would be no difficulty in showing why the great inventions of Watt and Stephenson were not made at an earlier period, and that they were the fruit of seeds which were buried in the theoretical investigations of Copernicus, Kepler, and Newton.

Perhaps our future means for keeping our heat-household will be as different in style and appearance from our present ones as a turbine from an old mill-wheel, or a steam-engine from a horse-wheel.

AUDUBON'S LILY REDISCOVERED.

By Professor SAMUEL LOCKWOOD.

DISCUSSING the varied exhibits made of the natural sciences in the late Exposition at Philadelphia, *Forest and Stream* pays a high compliment to a collection of water-color paintings of "The Birds of New Jersey." These paintings are the work of G. B. Hardenbergh, a youth in New Brunswick, who, having heard, in the Rutgers College Grammar-School, a course of lectures on birds, by the writer of this, became at once an enthusiast, and, with the spirit of a devotee, gave himself up to the study of birds in their native haunts. By wood and stream, in all seasons, the young artist naturalist watches his subject, learns its habits, gets its attitudes, then

shoots it, and, in his study, with a knowledge of all its *posituræ*, produces a portrait that sparkles with active life. The figures are Audubon-like, of life-size, and every one is strikingly natural. And the trees and plants, too, are so accurate that any botanist can, at a glance, identify the species. Each picture has the Flemish peculiarity of scrupulous attention to details, being, in its own way, a bit of rigidly realistic art. All this commends the work especially to the naturalist, and is much in the spirit of the famous Audubon. And, joined to the youthfulness of the artist, it was just this realistic truthfulness which made these simple bird-pictures of New Jersey so attractive at the great Centennial show.

But, can we not see an intimate relation between this æsthetical outcome of the artist and his own ethical inwardness? All this tender care for the details, this high regard for the truthful narration of the pictorial story, comes of the scientific conscience. Its processes are directed by the religiosity of good, honest work; and thus form is given to what may be called, as its resultant, the conscientiousness of art.

And yet, strange to say, this charming naturalist and artist, this, so to speak, consecrated student of Nature in her own haunts, whom so long every one, both at home and abroad, lauded for his fidelity to Nature, has of late been under a cloud. Yes, the truthfulness of even Audubon stands under attaint of both ornithologists and botanists. Let us adduce the specifications.

Our boyish delight still lingers in memory over the reading of this wonderful man's account of his first sight of that bird whose celebrity, unhappily, has given place of late to an undesirable notoriety. In a burst of enthusiasm, in which the love of Nature and of country mingled, he called it "the bird of Washington," and that Science, to the end of time, should do the same, he named it *Haliaëtus Washingtonii*. Thus stands his behest to science in his "Ornithological Biography," vol. i., p. 58:

"He first saw it on the Upper Mississippi, in February, 1814. A few years after, he met with a pair near the Ohio River, in Kentucky, which had built their nest on a range of high cliffs. Two years after the discovery of the nest, he killed a male, which was the subject of his description. After this he saw two other pairs near the Ohio River. It seems not to have been seen by any other ornithologist. Though this bird is admitted as a species on the authority of Audubon, many ornithologists do not regard it as such; and, from Audubon's own testimony, there seems sufficient ground for doubting the validity of the species."—("American Cyclopædia," revised edition, article "Eagle.")

In one of those delightful "Letters on Ornithology," by Dr. Coues, now appearing in the Chicago *Field* (Letter IX., on the "Hawks"), occur these words:

"While we have gray eagles, and black eagles, and eagles without stint, my word for it, reader, this eagle business is about done to death. Let me beg you

not to publish the next eagle you kill. Eagle-stories are almost always 'fishy.' As to the number of different kinds of eagles in this country, believe me when I assure you that there never have been but *two* species discovered in all the length and breadth of this country. That famous 'bird of Washington' was a myth. Either Audubon was mistaken, or else, as some do not hesitate to affirm roundly, he lied about it. The two species are, the golden eagle (*Aquila chrysaëtos*), and the bald eagle (*Haliaëtus leucocephalus*).

This, surely, is somewhat terrific, and would indicate, in this instance, that truthfulness, the bright particular flower in a man's character, was badly wilted. As Patrick would say, "it does'n't become the loikes of us to talk back; and maybe it cowes us, just, to be found in disagramint with the great bird-doctor, who is possissed of the aridition of all the fowls that iver was, sure." So we will not openly differ with this accomplished man; and will even, like a devout Moslem, leave Audubon to those stern ladies known as the Fates, and thus will hasten to another instance in which, perhaps, even a lady may come to the rescue of the reputation of this remarkable naturalist.

If possible, Audubon has suffered worse at the hands of the botanists. From these gentlemen the famous student of the woods and fields has received a snub of the shabby-genteel sort, and of the most persistent character. In his "Birds of the South," and with his usual love of fidelity to particulars, as indicating the plant habitat, or surrounding, Audubon figured a yellow water-lily—not that very ordinary flower, the *Nuphar advena*, the spatter-dock, or yellow pond-lily, so common from Canada to Florida, but a real close cousin to *Nymphæa odorata*, our delightful, sweet-scented water-lily. Beholding it with his own eyes, the great painter put it into one of his glorious bird-pictures, and, having given the portrait of his floral beauty, he also named it *Nymphæa lutea*, or, in plain English, the yellow water-lily. But this pretty flower had never been seen by the botanists; and so, forsooth, the thing was absolutely ignored—treated as a pretty fable, a bit of art extravagance. Art, like history, may have its anachronisms, but the real artist, though he err, cannot lie. So thoroughly was that *Nymphæa lutea* snubbed, that it would have been as much as a poor mortal's reputation was worth to have mentioned credence in the thing in the hearing of sober Science. One might look in vain in any botany of the South for Audubon's yellow water-lily. Not a word can you find in Darbey's "Botany of the Southern States;" and the same ominous silence pervades that later and more pretentious work, Chapman's "Flora of the Southern States." This luckless lily of Audubon is scientifically tabooed. Luckless, was it said? Well, this abjured beauty of the good man has fallen into luck at last. When neither sought nor expected, a species of poetic justice has lately been reached; for, in the person of a lady, learned in such lore, we have "a Daniel come to judgment." Last summer, in Florida, Mrs. Mary Treat rediscovered the long-lost flower

of Audubon. Yes, there it was blooming in those semi-tropical waters, and, from its golden chalice, this excellent lady drank the exquisite pleasure of a scientific discovery, and, sweeter still, the privilege that she could bid pass away that cloud of incredulity of over a generation of years. In fact, it was communicated to that Nestor of American botanists, Prof. Gray, and was duly acknowledged. It was truly the long-ignored *Nymphæa lutea*—Audubon's yellow water-lily. And, more than this, this deported beauty, through our modern Portia's zeal, is to be introduced to the best botanic circles of the world. Mrs. Treat has provided a liberal stock for the botanic garden at Harvard; and the curator, Prof. Sargent, is giving them careful and skilled culture, and is also supplying the gardens of Europe with specimens. Among the botanists, then, Audubon and his beautiful water-lily today stand quoted above par. Whether the "bird of Washington" is to reappear, and set this early ornithologist right with the modern bird-men, perhaps may hardly admit of a hope. That Audubon, like Wilson and the rest, did sometimes err in the diagnosis of his species, was easily possible; that he could lie, we think, was impossible. Much work of these earlier students has had to be done over again, and, as Dr. Coues has shown, this is emphatically true of the *Falconidæ*, or diurnal birds of prey. Very radical undoing has been needed of the work done on the eagles. Lately, we had at our very doors not less than three notable eagles—the black eagle, the gray eagle, and the bald eagle. But more thorough and skillful work has eliminated two out of these three species by showing that the black was the young, the gray the middle-aged, and the bald the mature, or adult stage, all of one and the same species, namely, the *Haliaëtus leucocephalus*—the bald eagle. We would like to see some condonement for the long ignoring of that Southern lily. If it were scientifically orthodox to rechristen that rediscovered flower, we would have its history crystallized in a new specific name, *Nymphæa Audubonii*, which, after so long incredulity, would be doing the bonny thing; and thus the yellow water-lily would dot, with golden memories of the gentle enthusiast, Audubon, the waters of the river of time.

THE PLANT-EATERS OF NORTH AMERICA.

By Professor SANBORN TENNEY.

THERE may, perhaps, be a question in the minds of some, or even of many, as to what animals are absolutely the most useful to man; but there can be no question that those which furnish him with milk and flesh for food, wool and leather for clothing, and which bear his burdens and draw his loads, have very high claims to this rank.

The deer, the antelopes, the sheep and goats, and the oxen, are indeed very intimately connected with our comforts, and even with our luxuries. And the North American representatives of these useful animals deserve our careful attention and consideration; for they are more intimately connected with our welfare as a nation than we yet fully appreciate or even understand. As all of our domestic sheep and cattle have come from wild species, so in the future we are to draw from the same sources some of the most valuable grazing animals that are to stock the pastures and farm-yards of the great farming-regions of this vast country. And we have several kinds of these animals now wild on the plains and in the forests that ought to be added to our domestic flocks and herds; and intelligent legislation should at once be inaugurated to secure this result, which is intimately connected with the welfare of every person on this continent.

Of deer there are in North America perhaps eight species: the black-tailed deer of the Pacific coast; the mule-deer, and the white-tailed deer, of the Upper Missouri region and westward; the common deer of the United States east of the Missouri; the wapiti of the northern and northwestern portions of the United States; one or two species of reindeer; and the moose of the northern portion of the continent.

The moose (*Alce Americanus*, Fig. 1) is the largest member of the deer family, equaling a good-sized horse in bulk, and having very long legs; and the male has very long and broad antlers, which in some instances weigh as much as seventy pounds or more. Its muzzle is exceedingly large and long, its ears long and hairy, its neck short and thick, and the latter and the shoulders covered by a mane, and the throat with long hair. The general color is a grayish brown, and the hair is very coarse and brittle. In its movements the moose appears quite awkward, but it is able to make very great speed, striding along without apparent effort over fallen trees, fences, and other obstructions, which would be serious obstacles in the way of most, if not all, of our domestic animals. The moose is still common in the unsettled parts of Maine and Northern New York, and thence northward toward the frozen regions. In the winter it keeps mainly on the wooded hill-sides; and at this time many of them stay in what the hunters term "yards." These are large tracts of ground over which the snow has been trodden hard by the moose, the lighter and untrodden snow forming a wall around the yard. There are generally in each of these yards one male and one female, and one or two fawns. They feed upon the bushes and the saplings that may be growing in the yard, and even peel off and eat all the bark from the hard-wood trees up as high as they can reach. They are especially fond of the birch, the moose-wood, and the poplar.

In the summer the moose frequents lakes and rivers. Here, by

going into the water, it escapes the attacks of the troublesome flies, and avoids injuring its antlers, which at this time are growing, and are very tender.

FIG. 1.—THE MOOSE (*Alce Americanus*).

The antlers are the most curious things, perhaps, in the structure of these animals. As already stated, they are found only on the males. They are shed annually, in the month of December; in some cases, however, they are carried till the following March. The first year the antlers are merely short knobs; the second year they are four or five inches long, with a single point; the third year about nine inches long; the fourth year they become broad with a brow-antler and several points, and about the fifth year they reach their maximum size. It is a matter of wonder that the enormous horns of these animals grow in about two months! They begin to appear about the latter part of March, or early in April, and in June or July they are full-grown for the season. While growing, they are invested with a skin which is covered with a sort of velvet-like pile; and this skin is nourished by a system of blood-vessels. When they have attained their full growth for the season, the skin peels off, and leaves the antlers at first perfectly white, but exposure soon turns them brown.

The female produces her young in May; at the first birth there is

only one fawn, but afterward two, and it is believed by the hunters that these twins are always one male and one female. The moose is hunted at the yards, and also pursued with dogs until it is fatigued and overtaken; and it is also shot on the lake-shores and river-margins, in the early autumn, by moonlight. The flesh of the moose, though rather coarse, is highly prized as food by many, and is a very good substitute for beef. The nose and the tongue are regarded as great delicacies. The marrow from the shank-bones is used by the hunters to spread upon their bread and eaten as butter.

It may be stated here that our moose is so nearly like the great elk of the northern part of Europe, that there is still perhaps a question whether the two are of one species. A fossil elk has been found in the marl beneath the peat-bogs of Ireland, which is of an entirely different species from any now living. This fossil elk was ten feet high to the top of the horns, whose tips are ten feet apart!

People generally think of the reindeer only as an inhabitant of the cold portions of Europe. But North America has at least one species of reindeer, although it is more generally called caribou. The woodland caribou, or reindeer (*Rangifer caribou*), of New Brunswick, Maine, and westward to Lake Superior, is thought by some to be identical with the reindeer of Lapland. The barren-ground caribou, or reindeer (*R. Groenlandicus*), is found in the arctic regions beyond the limits of trees, and may be only a variety of the former.

Unlike the other deer, the reindeer have the horns present on both sexes. The horns are palmated only at the tip, but, like those of all other deer, are shed and renewed periodically. The history of the reindeer of Lapland is well known, and from that history we learn how useful our own species may yet be made. As is well known, the Laplanders have large herds of these animals, and use them for beasts of burden and for draught, their milk and flesh for food, their skins for clothing and for covering their sledges. The reindeer is a very hardy animal, and draws the sledge of its owner with great speed. In one of the palaces in Sweden there is a picture of one of these animals, which is preserved with great care, from the fact that the animal from which it was painted drew the sledge of an officer, with important dispatches, the distance of eight hundred miles in forty-eight hours!

The caribou or American reindeer (Fig. 2) is considerably larger than the common deer, now so often seen in our parks. Its color is deep brown in summer and grayish in winter. In the winter this animal stays in the swamps, much of the time, and feeds mainly on the mosses and lichens that hang from the trees and bushes, but in early spring it retires to the hill-sides and feeds upon the buds and twigs. Like its European relation, it is very fleet of foot, trotting, or galloping, or leaping, with the greatest ease; and it is also capable of great endurance. For more than a week hunters have followed a

caribou before they could get near enough to shoot it. When attacked by dogs it stands at bay, and then falls an easy victim to the hunters. In the regions far to the north, where the caribou is plentiful, these animals move in herds from ten to a hundred or more. When in good condition the male caribou has a layer of fat on the back and rump two or three inches in thickness. The flesh is an excellent article of food, being tender and of good flavor. The skin when properly

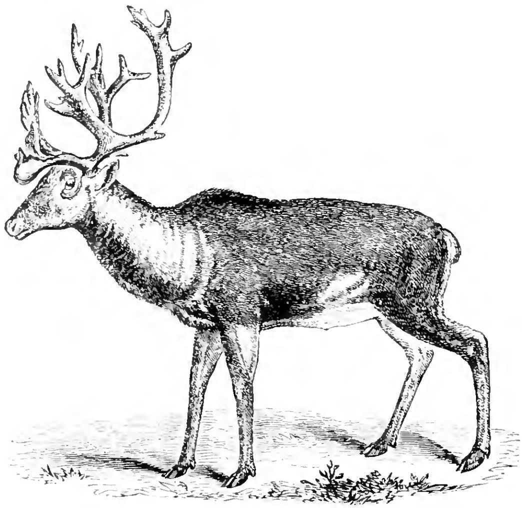

Fig. 2.—The American Reindeer, or Caribou (*Rangifer caribou*).

dressed forms one of the best articles for clothing to be worn in the cold regions. A suit made of the dressed skins of the caribou is so warm that it is said that the person wearing one of these suits and also provided with a blanket of the same material, may bivouac on the snow not only with safety but with comfort even in the intense cold of an arctic winter's night.

The common deer of Eastern North America, generally known as the Virginia deer (*Cervus Virginianus*, Fig. 3), is one of the most graceful and one of the most beautiful of all the deer family. It is now so common in parks that almost every one is familiar with it as it appears in this state of semi-domestication. But no one gets the best idea of this splendid animal who does not see it as it appears in the wild state, either in the forest or on the plains. Here when startled it bounds away with the most incredible velocity, and he who would bring it down must have a quick hand and steady nerve. This deer attains a weight of about two hundred pounds. The color is light brown in summer and grayish in winter, the under part of the throat and tail being always white. The food of this animal is exceedingly various. The tender grasses constitute its principal food in

summer, except in those regions, as in many parts of the South, where the deer can gain access to the fields of young wheat, oats, or other grain. In the early autumn it adds berries of various sorts to its bill of fare, and later still nuts and acorns; and in winter it feeds upon almost all kinds of buds and tender twigs, as well as upon various kinds of the more hardy herbs. The males are in excellent condition from August to November, and the females from November to January. The antlers are fully grown in July or August, and remain till the next January, when they are shed. The males engage in severe

FIG. 3.—THE VIRGINIA DEER (*Cervus Virginianus*).

contests with one another, and in some of these contests they get their horns or antlers interlocked, so that they cannot separate them, and the combatants at length perish from starvation and exhaustion. In some cases the antlers are interlocked so firmly that even a strong man cannot separate them, and Audubon mentions one case where three pairs of antlers were thus united. The flesh of this deer, as is well known, is tender and juicy, and has an excellent flavor. This fact, and the love of the excitement of the chase, have caused this animal to be extensively hunted. At the same time our forests have been disappearing, thus affording them less protection, so that the numbers of the common deer are far less than twenty-five years ago. It will require rigid legislation to keep these animals from entirely disappearing from many parts of our country where a deer-hunt is still possible.

Next to the moose, the wapiti or American elk (*Cervus Canadensis*) is the largest deer in North America. It is nearly as large as a horse, and its horns are the most magnificent to be found in the whole deer family, being five or six feet long and much branched. In some cases antlers of this species have been secured which were so long that when standing on their tips a man could walk upright through

the arch thus formed. Although this deer still lingers in the mountainous regions of Pennsylvania, and perhaps in a few other places in the eastern part of our country, it is confined mainly to the western and northwestern portions of North America, and south of the fifty-seventh parallel of latitude. In some cases it is found in large herds,

FIG. 4.—THE ELK, OR WAPITI (*Cervus Canadensis*).

all the members of which follow one of the males which is their leader, and whose movements they more or less closely imitate. The color of the wapiti is grayish in winter, and chestnut-red in summer. This deer is the analogue of the stag or red deer (*C. elephas*) of Europe, and was formerly regarded as identical with the latter; but it is a very much larger animal than its European relation, and is in every way a distinct species.

The antelopes differ from all the deer in having their horns permanent and hollow, and, like a sheath, covering a conical process of the frontal bone. In this respect the antelopes are like sheep, goats, and oxen. The antelopes have the horns round, curved, ringed, or wrinkled, and always black. There are many species of antelopes, no less than ninety having been described. Of these, two are found in North America, two in Europe, and all the rest in Asia and Africa.

Our most interesting species of antelope is the prong-horn (*Antilocapra Americana*, Fig. 5) of the western portions of North America. It is about the size of the Virginia deer, and is covered with coarse,

thick hair. Its color above is yellowish-brown; the rump and under parts white; the horns, hoofs, and the naked part of the nose, black. The white hair covering the rump is very long, and seems to be under the perfect control of the animal, and is at once made to stand erect when he is in the least excited; and it is wonderful to see this patch of hair rise and fall with his varying emotions. About half-way up the horns of the adult there is a branch or prong, and from this fact the animal gets its popular name.

The prong-horn is often seen alone, more frequently perhaps there are several together, and in some cases herds of one or two hundred

Fig. 5.—The Prong-horn Antelope (*Antilocapra Americana*).

are seen. It is not an uncommon thing for the traveler on the Pacific Railway to see several of these beautiful animals while he is crossing the Plains. One has been seen to run along for a mile or two parallel with the moving train, as if determined to keep up with it. Its speed is very great, and is only equaled by that of the fleetest of the deer; and hence it is almost useless to pursue it. It is not, however, difficult to secure these animals. They have great curiosity in regard to any objects which they are not accustomed to. The hunters well know this fact, and turn it to their own advantage. When the experienced hunter sees a prong-horn, or a herd of them, he does not pursue them, but keeps his ground, or little by little advances very slowly. The antelope soon advances a little toward him. The hunter waves his handkerchief, or a rag; the animal approaches still nearer and nearer; and in this manner he is soon within easy range of the hunter's rifle. It is stated that the Indians have the habit of lying flat upon their backs, and kicking up their heels with a rag or something fastened to them; and that by this process they entice the prong-horn to within such a distance that they kill it with their bow

and arrow. The flesh of the prong-horn in autumn, when it is in the best condition, is good food, especially if the animal be young.

In May and June the prong-horn brings forth two fawns, which are of a dun-color, and not spotted like the fawns of the deer. For these the mother displays great affection, and defends them with vigor against the attacks of enemies. She is sometimes able to beat off even the wolf; but not always, and hence many of these little creatures are annually destroyed by this hungry animal. The prong-horn, when taken young, is easily tamed. The writer has seen a tame one. It was thoroughly domesticated, and, whatever its wanderings during the day, it returned to the farm-house at night. It allowed itself to be freely handled, even by strangers. It followed the children as they went to school, and then returned to its home again, alone; all showing how easily it can be added to the stock of domestic animals of the farm.

Our other species of antelope looks so much like a goat that it has been named the mountain-goat (*Aplocerus montanus*, Fig. 6). It is about the size of the domestic sheep, and has small, round, slightly

Fig. 6.—Mountain-Goat (*Aplocerus montanus*).

recurved horns, which are ringed at the base, and which are jet-black in color, and polished, and are much like those of the chamois; the body is covered with long, white hair, and there is a long pendent tuft of hair under the chin. This antelope lives on the rugged portions of the Rocky Mountains, and seldom descends into the plains. It leaps from crag to crag, much after the manner of the chamois of the Alps, and in many portions of the mountains is secured with great difficulty. The flesh of this species is rather dry, and is not so highly prized as that of the other animals described in this article. It may be added here that the hair, or covering of the body, is of two kinds, the one being long and straight, and the other, which forms a thick, close under-coat, being a sort of fine silk-like wool.

Of sheep there is only one wild species in North America, the Rocky-Mountain sheep, or big-horn (*Ovis montana*, Fig. 7). This animal is of a much larger size than the ordinary domestic sheep, and its horns are of enormous size. A large animal of this species weighs about three hundred pounds. In Siberia there is a wild-sheep, called the argali, which Cuvier believed to be the same as our big-horn. It is certainly very remarkable that there should be only one species

FIG. 7.—THE MOUNTAIN-SHEEP (*Ovis montana*).

of wild-sheep on this continent, and that that one should be confined to our highest system of mountains. The inquiring mind naturally asks, "Whence has this sheep come?" But this question is not easily answered. It may, however, be stated here that Cuvier was inclined to believe that it came from Siberia, and crossed Behring's Straits on the ice.

The Rocky-Mountain sheep lives in flocks, and is exceedingly wild, especially in regions that have been frequented by the hunters; and he who would get a shot at one of these animals has often to make wide *détours*, and always to proceed with the greatest caution. The flesh of this animal is very highly prized, being regarded by some as even better than venison, or ordinary mutton. The hunters tell remarkable stories of the big-horn. They assert that this animal will leap sometimes from high precipices, head foremost, and, striking upon the tips of its enormous horns, bound away on its course as if nothing had happened!

Characteristics belonging to different kinds of animals are some-

times combined in one and the same animal. The musk-ox (Fig. 8) furnishes us with an example of this sort. This animal is in some respects so much like a sheep, and in others so much like an ox, that naturalists have named its genus *Ovibos*, the first part of the word meaning sheep, and the latter part meaning ox. The musk-ox (*Ovibos moschatus*) inhabits the barren ground of North America, and is about the size of a two-years-old heifer. Its horns are close together on the top of the head, whence they curve outward, downward, and thence upward. The body is covered with long pendent hair, and the color is brownish-black. This hair or wool might be made very serviceable in the manufacture of useful fabrics, if it could be obtained in sufficient quantity. The musk-ox lives mostly in herds of a score or more, and, contrary to what we would naturally suppose, it runs with great speed, and climbs rocky hills with facility. The flesh of the young animals is very good, but that of the older ones is too strongly impregnated with musk to be palatable to white men, although the Indians and Esquimaux may not seriously object to it.

Fig. 8.—The Musk-Ox (*Ovibos moschatus*).

It is much to be regretted that the musk-ox is so rarely preserved in our museums. It is exceeding difficult to secure a specimen, as almost every one which is killed by the natives is immediately devoured by them. The food of this animal consists of grasses in the summer and lichens in the winter, the latter being obtained by scraping the snow from the ground. On this food they keep in remarkably good condition. It may be added here that only one species of musk-ox is now living; although their fossil remains show us that in the past there have been other species of this animal, and in other parts of the world than America.

It is interesting to see how the same idea under specifically different forms is represented in the animal kingdom in the different portions of the earth. Take the idea which finds its expression in the ox, for example. In the southern part of Africa we find the ox in the

form of the Cape buffalo, a very ferocious animal, with horns so wide that they nearly cover the forehead; in India, the arni, whose enormous horns are ten feet apart from tip to tip; in the forests of Lithuania and of the Caucasus, the aurochs, an ox related more or less closely to our wild species; in Tartary, the grunting cow or yak, which is smaller than any of the preceding, and which has a long mane upon the back, whose tail much resembles that of a horse, and whose grunting is similar to that of a hog. And in North America we find the American buffalo (*Bos Americanus*, Fig. 9),

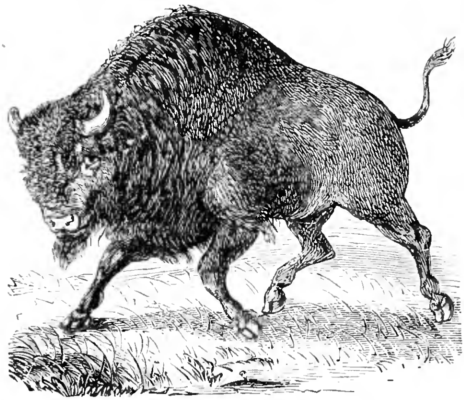

Fig. 9.—The Bison or Buffalo (*Bos Americanus*).

the largest quadruped on this continent. This animal once inhabited nearly all of North America, except the cold regions of the north; but it is now confined mainly to the great Western plains, where, notwithstanding the immense havoc made among their numbers, both by Indians and white men, they still exist in numbers that almost defy computation, in some places covering the plains in every direction as far as the eye can reach. The buffalo is as large as a good-sized domestic ox, and has a large head which is carried close to the ground, a broad forehead, a broad, full chest, a large hump between the shoulders, narrow loins, and rather slender legs. The horns are set far apart, are large at the base, and taper suddenly to a sharp point. The buffalo is covered with a thick coat of hair, that upon the head, neck, and shoulders, being very long and shaggy. The horns and hoofs are black. Perhaps there is no grander sight to be witnessed among the larger animals than to see one of the immense herds of these animals, when under good headway, sweep by—if only the observer has a safe standing-place.

When the buffalo is moving rapidly, it progresses by an awkward canter or gallop, and it requires a good horse and an expert rider to keep up with it. The hunting of the buffalo is one of the most exciting and at times one of the most dangerous sports, if such it may

be called, in which the visitor to the great Western plains can engage. Unless shot through the heart or some other vital part, this animal is not easily brought down. When the animal is only wounded it becomes very furious, and, if its pursuer be on foot, it at once attacks him, and the hunter has all he can do to save himself from destruction. Nor is he always safe even if he be mounted, unless he can manage to keep out of the way of the infuriated animal, for he ferociously attacks both horse and rider.

Buffaloes wander much from one region to another in search of the best pasturage, and of water, salt, or saline springs. In the winter they move southward, and in spring return again to the north. Their deep and well-trodden paths traverse the plains for hundreds of miles. Vast numbers are destroyed during their spring and autumnal migrations. Many perish from starvation; those that get weak and are left behind, are harassed and at length devoured by wolves. Sometimes the vast herds attempt to cross the rivers upon the ice, and, when they are crowded together, the ice gives way and they perish in the cold waters.

The male buffaloes have terrible combats. The young are born in April and May, and there is generally only one at a birth. The young are in constant danger from the wolves.

The buffalo is easily domesticated, and should be added to our stock of domestic cattle. The flesh of the wild ones is extensively used for food, and is regarded with much favor; and we already know enough to convince us that the flavor of their flesh would be improved when they are fully under the dominion of man. Experiments show that the males make excellent oxen, and that they are stronger and swifter of foot than the ordinary oxen; and, when we consider that it takes the milk of two domestic cows to properly nourish one buffalo-calf, we may safely conclude that the females will make excellent domestic cows.

The buffalo was once common over most of North America west of the Hudson River. In the Carolinas they were found even on the seaboard. But, like the red man, they have fled westward, before the advance of civilization, and are still fleeing. Their natural feeding-grounds become cultivated fields. Enemies are constantly on their track. Man hunts them for their valuable skin and for their flesh. Vast numbers are killed yearly that civilized man may feed upon their tongues. Wolves and bears lurk in ambush to snatch away the young, and more openly to wage a constant warfare against the sick and disabled members of the herd. So that, notwithstanding their vast numbers, the day is not far distant when the buffalo will be as rare a sight on the Plains as the wapiti and the moose are now in our Northern forests.

THE SCIENCE *vs.* THE ART OF CHEMISTRY.

By IRA REMSEN.

THE attitude of the world in general toward chemistry is peculiar, and, as this paper is intended to show, it is not what it ought to be. This is due in turn to a peculiarity of the science itself, which distinguishes it from most other sciences. We refer to its close connection with matters of every-day experience, and of practical importance. It is unnecessary to dilate here upon this close connection. Every one who has any conception whatever of chemistry recognizes it to a greater or less extent. But, owing to this close connection, the unscientific world has grown into the habit of considering the practical problems as the problems *par excellence* of chemistry; and, having once recognized *some* object of the science, they inquire no further, and hence they fail to recognize its most important and only legitimate object.

In this respect chemistry as well as physics is unfortunate; though at the present day physics has an advantage over chemistry. Time was when the world looked upon physics also as mainly a practical science; but, of late, by the efforts of gentlemen of high standing, the attention of the people has been drawn to some of the higher problems of the science, and these have been rendered intensely interesting to every thinking being. Some of the grander results of physical investigation have also become familiar to the world, and have served to increase the respect for the science. The great truths of the conservation of energy and the transformations of energy; the application of the spectroscope to the investigation of heavenly as well as earthly bodies; the undulatory theory of heat; the nature of sound, and the beautiful relations of sounds to each other—these are all matters with which the world is fast growing familiar; and the popular discussion of these subjects is doing something, perhaps a great deal, to elevate mankind above that condition of superstition and darkness which still is the portion of most of the world. The great generalizations of science are ennobling, and, in the exercise which they afford the intellect, are productive of happiness of a very high order. Whatever good we may recognize, as having been effected by the practical application of electricity, heat, and other natural agents, to the satisfaction of the wants of man—and the good is undoubtedly great—an infinitely greater good springs from the dissemination of the immortal truths of physics. But the latter good is quietly effected; it consists in a growth of the ideas of the world, and thus contributes to the growth of manhood. We do not always recognize it, but it is ever present. With the growth of ideas concerning the physical universe, the ideas concerning the Creator of the universe must grow

larger, broader, grander, and we must worship with a truer adoration, and a feeling of more perfect reverence.

If we turn again to chemistry, we shall see that while its importance is almost universally recognized; while the number of those who devote themselves to its study is increasing every year; while immense sums of money are yearly spent for the building and support of palatial laboratories; while the press, recognizing the popular appreciation of the science, furnishes, in its own peculiar way, brief records of its advance—still we can point to very little connected with chemistry which, for its elevating influence upon mankind, can be compared with the great physical truths above referred to. That which is caught at and served up for the public is taken from the lower portions of the science, while the higher portions pass on, scarcely if ever coming in contact with the populace. The public knows when a new dye is discovered; it knows when the poison has been found in some strange stomach; it knows when a new milk for babes has been concocted; it knows when precious metals have been detected in the depths of the earth; it knows all these things because it is promptly informed in regard to them; and it is right and good that the information should be given, and that these things should be known. It is plain, however, that a thousand dyes might be discovered; that a thousand murderers might be brought to justice through the aid of the chemist; that varieties innumerable of milk for babes might be concocted; or that mines upon mines of gold might be unearthed without the slightest ennobling or elevating influence being exerted upon the mass of mankind. All of these things would be valuable—undoubtedly—but their value would be of a very material kind. It is certain that this material value is that which is most easily recognized, which appeals most directly to the public; and hence plainly, in the public mind, the importance of chemistry is measured by the standards of this value. The reputations of chemists, too, depend upon the greater or less extent to which they devote themselves to practical questions. He who is frequently on the stand to testify in regard to cases of poisoning; he who succeeds in presenting to the world some new compound which can be used practically; he who detects impurities in our food or tells us of poisons where their presence must be of importance to us—this man is, to the public, *the chemist.* Ask ninety-nine men out of a hundred what a chemist is, and they will give a definition of one who practises the art of chemistry, rather than of one who is devoted to the science of chemistry.

This statement is true, whether we speak of the mass of mankind, or of educated and even professional men. The reputation of the science, at the present time, is such that few men conceive of the true science independently of the art of chemistry. This is true, further, not alone in this country, but in Germany, which may rightly be called the seat of chemistry—with this difference, however: In Germany

the true scientific spirit is so deeply imbedded in the educated mind, that a subject which has a practical side is apt to be looked upon in a disrespectful manner; and so it happens that those who ought to know better are inclined to speak contemptuously of chemistry, simply because they accept the popular idea of the science as the true one, not stopping to ask whether there is anything higher in the subject than that which the public recognizes. An anecdote which illustrates this matter clearly may not be out of place here. Two students at a German university, one a philologist, the other a chemist, were conversing, on the eve of their examination for the degree of doctor of philosophy. The philologist asked, "What is the subject of your thesis?" The chemist answered: "Piperic acid; I have been working on the subject for a year and a half." When it was further stated, in reply to inquiries, that this acid could not, so far as was known, be used for any practical purpose, the philologist was loud in his expressions of pity for one who could work a year and a half without accomplishing something which would tend directly to improve the material condition of our race. A counter-question in regard to the subject of the thesis of the philologist elicited the answer: "My subject is an exceedingly interesting one; I have already written nearly a hundred pages on it and have not yet finished: it is *the preposition* AD *in Tacitus*." It is needless to add that he was unable to state to what practical use the preposition *ad* could be put. The condition of mind toward chemistry which this young man thus betrayed is that which we should most frequently find in educated as well as uneducated men in this and other countries. We would not throw ridicule upon the enthusiasm displayed—we admire it; but we ask to be allowed to have a similar enthusiasm for our prepositions.

We have thus found the chief cause for the idea commonly held in regard to the nature of chemistry to be that peculiarity of chemistry among the sciences which gives it its close connection with practical matters. It has already been remarked that it is right that this portion of chemistry should be recognized and appreciated. This recognition and appreciation should be encouraged, but not to such an extent as to sacrifice any appreciation which it is possible to awaken for the higher portions of the science.

There is another direct cause for the popular conception of chemistry, growing out of the more general and indirect cause already considered. This consists in bad attempts to present the truths of the science to the people. The popular lectures on chemistry which are usually delivered are not scientific lectures; they are frequently utterly lacking in everything that characterizes scientific method; and they leave no further impression on the minds of the hearers than that chemistry is a subject which enables men with the requisite degree of skill to become successful showmen. Though the lecturer is perhaps more respected, still the character of the respect which he has

called forth is akin to that called forth by any clever trickster. It is unfortunate that experiments, originally devised for the purpose of teaching facts, should have come to be employed simply for the sake of their æsthetic effects. There can certainly be no harm in making an experiment a thing of beauty, so long as its real object is not by this means interfered with; indeed, this may be advisable, in order more strongly to impress upon the minds of the hearers the facts which are to be taught, but the tendency is very strong toward the condition above described: the science is made to serve the purposes of showmen, and the rabble shout the more, the greater the display. Those who serve up this class of lectures are doing positive harm by belittling the science whose name they profane; and they are also doing negative harm by failing to make use of the opportunities afforded them to draw the minds of men upward to higher conceptions, and thus of elevating mankind. They neither recognize the science nor the art of chemistry, but by their actions teach that it is a pastime of no particular value.

In the foregoing we have drawn a line between the science and the art of chemistry. The character of the art is perfectly plain to every one. He who analyzes substances in order to decide questions solely of practical importance; who examines the properties of substances solely with a view of determining the practical uses to which these substances can be put; whose only problem relates to the applications of the truths of chemistry to the uses of man—*he* practises the art of chemistry.

But it is time to inquire what the science is, and what its relation to the art is. A science is a collection of principles, well established, applying to a certain class of phenomena. The science of chemistry is that particular science which treats of the action of bodies upon each other, in so far as this action causes a change in the composition of the bodies. All the so-called natural laws which govern this kind of action belong legitimately to the field of chemistry. The science is, strictly speaking, a part of that broader science which treats of the action of matter upon matter, viz., physics; but it is usual to consider the two as separate sciences. Its first object is to determine the laws of combination and decomposition of bodies, and its state of perfection will be reached when so much is known concerning these laws that we shall be able in every case to foretell what changes will ensue when two or more bodies are brought together, or when certain influences are brought to bear upon a body. We are so very far from this perfect state at present that we cannot even say what kind of reasoning processes will be necessary to enable us to draw the proper conclusions from given facts. It appears probable, however, that chemistry will gradually develop into a true mathematical science, and that, having reached this state, chemists will determine the orbits of atoms, their rates of motion, their perturbations by methods similar

to those so long employed in studying the problems of astronomy. Although we are far from the perfect state of the science, still every advance made in it is a step toward the end. From time to time material enough is collected to enable some one to make a comprehensive generalization. These generalizations we admire, but we sometimes forget that they never could have been made had not a myriad of workers from day to day furnished the material; themselves often unconscious of the importance of the real work they were doing, but believing that every fact established, however insignificant in itself, every error of previous observers, however slight, corrected, would at some time serve a purpose in the growth of the science. Dalton's law of multiple proportions; the law of Dulong and Petit connecting the specific heat and the atomic weight of the elements; Avogadro's hypothesis relating to the connection between molecular weights and the volumes of gaseous compounds, would still have been of the future, had it not been for the efforts of a great many scientific workers, contributing their mites day by day.

Though we thus recognize a growth of the science of chemistry, entirely independent of any practical applications of its facts, it is of course true that the latter follow closely in the footsteps of the former. When, then, we rejoice in any useful application, let us remember that it could never have been made had the science itself, as a science, not advanced.

It happens in this country particularly that a man may both practise the art of chemistry and at the same time be a worker in the field of scientific chemistry. This is due to the fact that it is necessary for the men to live, and there are very few positions in the country which enable their incumbents to devote themselves to the pure science of chemistry without obliging them at the same time to look for additional means of support to that furnished by the positions themselves. This additional means of support can usually be found most readily in the practice of the art of chemistry. Too often, time that could and would be devoted to grappling with the problems of the science is given up to the art in order to keep the purse supplied. Every properly-constituted scientific man, however, who is obliged to so apply his powers as to bring himself immediate and material rewards, feels that he is doing something which he would rather not do, and that, by applying himself to his science proper, he could in the end be of much more service to the world. It is apt to be the case, too, that he who begins to slight the science and to favor the art will at last entirely sacrifice the former for the latter, and we see too many teachers of chemistry in this country at the present day who are devoting their time to the art rather than to the science of chemistry; a circumstance which has the most pernicious effect upon the growth of the science among us, for the students who are placed under the influences mentioned are not stimulated, as they should be, to con-

sider the higher questions of the science, but go out into the world only to keep alive the popular and erroneous idea concerning the nature of chemistry.

Finally, if we have correctly represented the attitude of the world toward chemistry, and correctly stated the causes of this attitude, it is plain that the world is not to be blamed, but rather, if fault is to be found, it must be with the chemists themselves. To them we must look for deliverance. They may by united efforts bring about the desired changes. But how?

Two general methods may be indicated. In the first place, the teaching of chemistry must be of a higher order than it is at present. In some of the higher institutions of learning students must be carried through strictly scientific courses; they must be brought face to face with the great questions of the science, and shown how to work at the solution of existing problems; and they must go forth with high and true conceptions concerning their science, prepared to influence those with whom they come in contact, and to give them, too, correct ideas. A great deal can thus be done in the right direction by a single strong man teaching properly, and the influence is very quickly felt. We need only refer to the influence of Agassiz on the science of zoölogy in this country, to show what results may be reached by a single man who is working in the proper way. A change in the methods of teaching in our higher institutions of learning, then, is the chief thing to which we are to look for an improvement in the popular conception of our science. But there is another means at our command which is very rarely taken advantage of by scientific chemists. This consists in popular presentations of the higher truths of the science, either in the form of lectures or of articles in magazines which are read by the public. A great deal of good can be accomplished in this way, if the work is properly done. There are chapters of great inherent interest treating of matter which belongs in the domain of the science of chemistry, and these are rarely alluded to in popular lectures or articles. If more stress were laid upon such subjects, and less upon the merely practical portions of the science, something would be done in the way of drawing the attention of the public toward the higher questions, and thus that good influence which was above referred to as resulting from popular discussions of the great truths of physics would also be felt, to some extent, in connection with chemistry. Thus, too, there would gradually grow up a respect for the science as well as for the art of chemistry.

VITAL STATISTICS.

By CHARLES P. RUSSEL, M. D.

NO subject of scientific research has within the present century received more earnest attention from thoughtful minds than that of statistics. None, moreover, is more worthy of investigation or fruitful of more satisfactory practical results to humanity. It must be confessed that careless or dishonest observers occasionally misconstrue or misinterpret the significance of statistics; but the same is equally the case with all facts. There can be no doubt that certain truths are demonstrable by figures, and that we must accept almost without qualification the old adage that "figures cannot lie." We should not confound with statistics themselves the erroneous deductions drawn from them so frequently.

Among the various divisions of statistics the one which relates more particularly to birth, marriage, and death, must always occupy the most prominent place in human interest. It is this to which the expression *vital statistics* has appropriately been applied, and as "self-preservation is the first law of Nature," so if by a study of this science we can, so to speak, grapple with Death himself and retard his course even for a time, we may assuredly congratulate mankind. This science, as its name implies, takes cognizance of the essential circumstances of human existence, while it must obviously possess inherent and intimate relations with other branches of statistical inquiry, viz., those of morals, industrial pursuits, customs and modes of life, material prosperity, peculiarities of soil and climate, domestic economy, and even political tendencies and events.

If the deductions gained from vital statistics are to be of value in the preservation of life, those facts which bear particularly upon the preventable causes of death must naturally claim our more immediate consideration. The subject of mortuary statistics is, indeed, one of profound interest. All civilized nations have finally recognized its importance, and have by more or less stringent legislative enactments enforced the collection, preservation, and proper arrangement and analysis, of those data which constitute its foundation. It must be acknowledged that even exact figures of mortality do not always indicate *with positive accuracy* prevailing conditions of the public health, especially in the case of affections subject to constant fluctuations of type. They are, however, indices which point unerringly in the right direction, and, as such, they are entitled to our most careful consideration. Moreover, they are our sole means at present for approximate investigation of national disease. We may trust that ere long the concerted action of the entire medical profession will furnish us with a constant knowledge of the comparative prevalence

of all disease. In the United States the want of such a system is in a manner compensated for by the periodical enumeration of causes of death at each national census. Although for obvious reasons such enumeration must be defective, both as regards the actual causes themselves and the number dying within the census year (the returns of 1870 being computed as forty-one per cent. less than the true number), still, the same sources of error and the same elements of truth obtaining, as a rule, in every section, the results of comparisons between different portions of the country contain much less of fallacy and more of fact than might be anticipated. For the last census year, ending June 1, 1870, nearly half a million deaths were collated and appropriately arranged by the Census Bureau, in tables referring both to the country as a whole and to separate States and Territories.

Among our English kinsmen across the Atlantic there has existed for many years a uniform and comprehensive system of death-registration. Thus, within a brief period of the outbreak after an epidemic, its mortuary figures from every quarter reach the central bureau in London, where they are at once systematically tabulated and published. The character of the morbific storm is studied, and its course predicted with almost as much certainty and promptness as each approaching disturbance of the elements is foretold and described in Washington from a comparison of manifold meteorological phenomena. In the same manner, whatever peculiarities may characterize the mortality by sporadic and endemic affections at different seasons, in various portions of the country, are observed and converted into numerical expressions for analytical study.

It is unfortunate for the cause of medical and sanitary science that no similar system has yet been established in this country. In our population of forty-odd millions over seven hundred thousand deaths must have occurred within the last twelve months; and yet, except in the case of our large cities, we are almost as ignorant of our causes of mortality as we are of those which cut off the population of China.

The British system, one applicable to the peculiarities of different populations, was devised by Dr. William Farr, the distinguished medical director of the English Registrar-General's office. A statistical congress, under the auspices of the French Government, was convened in Paris in September, 1855, to consider this subject, and it agreed upon a nomenclature of the causes of death substantially the same as that proposed by Dr. Farr. At another congress held in Vienna, in 1857, a uniform nomenclature and plan of registration for all the European states was determined upon. Dr. Farr's classification of diseases was not so generally adopted; but it has since been making its way in Germany and other portions of Europe. This nosological classification, though by no means perfect, doubtless possesses, in its practical relations to public health, advantages over every system that has preceded it. Its divisions are founded upon the manner in

which diseases of similar type or character affect the population. It will be sufficient to mention its first great class—that of zymotic diseases. This term *zymotic* is derived from a Greek word meaning *ferment*, and has reference to a change analogous to that of fermentation occurring in the blood by the infinite multiplication of disease-germs. Such affections chiefly comprise fevers *par excellence*—the epidemic, endemic, and contagious or infectious disorders—which suddenly attack masses of people, which spring from different sorts of malaria, or from specific communicable poisons; contaminate the atmosphere and water, and decimate in a brief time civil and military communities. We read in sacred history of whole armies having been suddenly swept away, as that of Sennacherib, which, while besieging Jerusalem, lost 185,000 men in a single night under the deadly breath of the destroying angel—a beautiful metaphor, probably, for the swift and invisible blow of the pestilence. It has been well remarked that these diseases distinguish one country from another, one year from another. They have formed epochs in chronology, and, as Niebuhr has shown, " have influenced not only the fall of cities, such as Athens and Florence, but of empires."

This great class of maladies is the index of salubrity; it is this class which varies to the greatest extent in different climates and seasons, which modifies the fatality of other kinds of disease, and which constitutes the principal difference between the health of different peoples and periods.

A general and uniform system of death-registration among nations renders easy what would otherwise be impracticable, viz., constant international exchanges and comparisons, not simply confined to individual affections, but applicable as well to immense groups of cognate diseases. In this manner statistics of mortality assume vast importance, and present for our consideration manifold questions of a physical, social, and political character. They determine the laws which regulate the duration of life; they indicate in what manner those laws have been or are being infringed, and afford bases for calculations materially affecting the interests of mankind. Statistics are far from being the barren array of figures ingeniously and laboriously combined into columns and tables, which some persons are apt to consider them. They constitute rather the ledger of the people, in which, as the merchant in his books, the citizen can read at once all the results of a week, a month, a year, or series of years, and can deduce the profit or the loss which has accrued to the account of vitality, morals, education, wealth, power. And it has been well said that " science has nothing to offer more inviting in speculation than the laws of vitality, the variations of those laws in the two sexes at different ages, and the influence of civilization, occupation, locality, seasons, and other physical agencies, either in generating diseases or in improving the public health."

But, putting aside this broad and philosophic view of the importance of mortuary statistics, it is evident that the application of their deductions must be of great benefit to the physician as a practitioner alone. This was perceived even as far back as the time of Sydenham, who inculcated the doctrine that the treatment of all disease should have a reference not only to the immediate symptoms and to the season, but also to the epidemic constitution of the year and the locality. It has been remarked by a distinguished author that "man is not born, does not live, does not suffer, does not die, in the same manner on all points of the earth. Birth, life, disease, and death, all change with the climate and soil—all are modified by race and nationality." Medicine, with the other natural sciences, has now been obliged to abandon vague hypotheses for truths determined by observation. Numerical expressions are substituted for uncertain and conjectural assertions. Only a limited number of facts are, however, contained within the horizon of a few observers. The determination of the laws of mortality requires a very wide range of observation, and a considerable space of time, in order to eliminate accidental perturbations.

The next important element of vital statistics is that of birth. Man is ushered into existence under natural circumstances almost as impressive as those which circumscribe his duration of life, and which attend its surrender. While tens of thousands are divesting their being of earthly garb, and entering upon their eternal inheritance, still greater numbers are assuming the heritage of life in forms moulded by antecedent events, and stamped with ancestral peculiarities. If, therefore, it be profoundly interesting to contemplate, arrange, and study the multitude of agencies which impel this innumerable caravan of pilgrims toward their destination, it is almost equally instructive to analyze the manifold causes which have contributed to their assembling together. Such particulars, when massed into statistics, become of acknowledged importance to medical and social science. The disparity in the sexes born at different periods, the average number of women bearing twins, triplets, etc., the proportion of offspring from native or foreign progenitors, the ages and occupations of parents, the average number of children produced at different periods of female life and in different seasons, the influence upon reproduction of the relative ages of parents, the reciprocal relations between illegitimacy and modes of living—these and other kindred questions are of deep concern to the human race, and the source of their solution lies in the largest accumulation of facts.

Moreover, the actual number of births occurring in any community each year is indispensable, in conjunction with other factors, for computing the increment of population during years intervening between those of official enumerations, and consequently for the determination of the true death-rate. The remarkable precision with which this

increase may be approximated is exhibited by the London tables, according to which the *estimated* population of that city on April 2, 1871, was 3,247,631; while the *decennial census* completed on the same night gave the number of the inhabitants as 3,251,804—a difference of *only about four thousand in three and a quarter millions*—one almost inappreciable in the calculation of percentages.

To the casual thinker, statistics of marriage might seem of little consequence. But, in fact, the deductions from a review of marriage-returns are of positive value not only to the moral philosopher, but to the political economist as well. The relations of marriage to various industries—to mining, agriculture, trade, commerce—in a word, to the material prosperity of a people—have been well established by statistics. A decided diminution in the marriage-rate of a community within a given period of time is an unerring indication that war or pestilence, or commercial crisis, or other great disturbing force, has rendered the necessaries of life dear, and occupation difficult to procure. The various forms of marriage—the numbers of bachelors, widowers, spinsters, and widows, united in wedlock; the tendency to early or late marriages among certain classes and peoples; the condition of elementary education as indicated by the proportion of men and women capable of signing their names to marriage-documents; the effect of a demand for skilled labor upon the proportion of early marriages; the relations between waste of life and proportions of marriages and births in towns as contrasted with rural districts; the influence of the marriage-rate on morality; the ratio of marriages to births, and its conformity to density and character of population, and to industrial pursuits—all of these considerations furnish assuredly social problems of deep and constantly-increasing importance to civilization.

WORLD-CREATIONS.

By C. C. MERRIMAN.

THE New-World pioneers of the sixteenth century, when they first looked on the sea-worn shores and giant forests of New England, had in reality no compelling reason for believing in the veritable old age of this new-found land. They had no "first order of proof" that the shores were not recently upheaved there for them to land upon, and with the growth of the centuries on them for the trial of the manhood that was soon to reclaim them. But I think those sturdy adventurers, if they stopped at all to consider of scientific doubts, were not long in deciding that the scene before them was conformable to the laws and processes of Nature, and therefore must have been the slow growth of time.

In like manner, the geologist, looking into the bowels of the earth, and finding here and there the remains of a tree or a saurian, presumes that they once lived and grew in the same localities, and were buried and petrified under the rock-grindings of after-ages. But he really has no absolute proof of any such thing. They may have been created in the fossil state and laid away in the strata on the same day the earth was made. But I think the scientist, knowing laws of Nature by which, with sufficiently long periods of time, all these geologic results might have been gradually brought about, is justified in believing that they too were the slow product of Nature and of time.

So we, finding that the world has certainly at some time been subjected to a heat at least sufficient to volatilize nearly every known substance, and that there are laws of Nature by which, through periods of time immensely long, the earth and the planets might have been rolled up from a gaseous nebula and bowled off in their mighty revolutions, have just as much right to say that it was so, as we have to say that the American forests grew, or that the Triassic beds were deposited.

Geology has proved that the earth, up to the primary rocks, was once a molten mass. The crystalline structure of the unstratified rocks compels to this conclusion; for minerals insoluble in water can only become crystallized in large masses by cooling from a state of fusion. If, then, the earth was once an incandescent globe of melted rocks—for everything above the granite beds must then have been in a state of vapor—it is not unreasonable to suppose that it may have existed prior to that time in a still more highly-heated condition—even volatilized, and diffused through space as rare and attenuated gases; for this is the condition which all matter assumes under sufficient degrees of heat. In fact, we must either suppose that the earth was created as a fiery liquid globe, for which we have no warrant, or we must follow back to the time when its vapors were scattered in space, unreflecting and impenetrable to light—when the earth was "without form and void, and darkness was upon the face of the deep."

Let us start, then, with that condition of things which it is now very generally conceded must once have existed—the diffusion of matter in a nebulous form throughout all space. Calculations easily made show that the nebula must have been of extreme tenuity—such that the few grains taken up on the point of a knife-blade must have been expanded to fill several cubic miles. A heat so powerful—for we know of no other force which could thus hold apart the atoms of matter—would doubtless be sufficient to resolve every known substance into its simplest elementary constituents, perhaps into a very few primordial elements; for chemists are far from being satisfied that they have arrived at the ultimate forms of matter in their list of

sixty-five elements. But, however this may be, we know that the atoms, whatever they were, must have been held so far apart that no combinations could possibly have existed. Neither were they drawn more in one direction than another by their mutual attractions, for they are equally diffused through all space. Therefore, heat, the great repulsive force, has overcome all the forces of attraction—cohesion, chemical affinity, and gravity.

Between such mighty contending forces we can hardly imagine a state of perfect equilibrium. Immense currents and world-wide surgings must be the long-continued if not the permanent condition of this state of things, especially if we conceive it brought about by natural causes. More condensed portions of nebulous matter would be formed—sections of space larger or smaller, in which the forces of attraction counterbalanced those of repulsion. Each such section would then have its centre of gravity, around which all the currents within its influence, by the law of the composition of forces, must eventually unite in one. This one flowing ever around and slowly toward the centre, like a ball rolling down an inclined plane, goes faster and faster, until the centrifugal overbalances the centripetal force, and it separates completely from the inner mass. Thus a ring is formed revolving around a central nucleus. Unless perfectly equi-posed, and of homogeneous material, this ring would sooner or later break up into a number of globes, which, by the superior attraction of the largest, would ultimately coalesce into one. This globe, still contracting, and the nucleus also contracting, would throw off satellites and other planets, all revolving in nearly the same plane and in the same direction. All these processes are in perfect accord, not only with the conditions of the heavenly bodies so far as discovered, but with known natural laws. Many of them have been successfully imitated on a small scale in experimental illustrations, as in the rapid rotation of oil suspended in water.

We have here given only the simple outlines of the famous "nebular hypothesis" of Laplace. In later years, the discovery of nebulæ in the heavens in all stages of world-formation, the evidence of the spectroscope on the unformed material of the universe, and other proofs, have compelled for the proscribed hypothesis a recognized place in science. We do not stop to consider these subjects more fully, because it is the purpose of this article to inquire chiefly concerning the forces that would be engaged in such a process of evolution; and, firstly, how from the preponderance of the repellent forces holding matter in universal diffusion there came the final mastery of the aggregating forces ever concentrating, combining, and working up the materials of the universe.

The first of the operations which have come to our notice in the progress of this evolution is the condensation of the gases. This, according to all experience, ought to evolve heat; but, instead, we

find only that the flow of the currents—the motion of the masses—is proportionately increased. Is there a connection of cause and effect between these phenomena?

All motion that we are familiar with requires the expenditure of heat. The combustion of coal supplies motion to the steam-engine. The evaporation of water by the sun's heat causes the rain-clouds and the mill-streams. The oxidation of certain elements in the food we eat is the combustion which supplies our bodies with powers of motion. Recent discoveries have shown not only that motion is heat transformed, but that to produce a certain quantity of motion an invariable certain quantity of heat is required.

Again, the cessation of motion evolves heat. It is well known that by skillful blows with the hammer a cold iron bar can be made red-hot. Two wheels revolving in opposite directions, and touching at the circumference, become highly heated; and factories have been warmed solely by this transfer of motion into heat. Friction is but another name for the arresting of motion, and, as we well know, always produces heat. There is also here the same equivalence as in the other case. The stoppage of motion evolves just the amount of heat that was required to produce that motion.

The greatest triumph of modern science is the splendid induction that all the forces are correlative and indestructible. Not an impulse of motion, of light or heat, or any force, is ever lost. It may be communicated from one body to another, or transmuted into some other form of force, or become for a time latent or imperceptible; but it always exists, and is reclaimable back again into the same, in mode and quantity, from which it started.

The grandest exemplification of these truths will be found in what we are now considering, the origin of the celestial revolutions. The condensation of gases gives out heat in direct proportion to the contraction of volume. The attraction of gravitation, not only between masses but between all the particles of matter, increases in the inverse square of the diminishing distance. From these two principles it can be mathematically shown that in the contraction of each great world-nebula heat would be set free in the precise proportion of the increase of atomic attraction; or, in other words, that it would take the exact amount of heat-force that had been released, to separate the atoms again to their original distance apart. But in this instance the heat-force is not really set free; it is transformed into the motion of the mass from which it came. Instead of holding the atoms apart, the work which it now has to do under the form of motion is, to prevent the masses from falling into each other. It is this motion —the celestial revolutions—which keeps the worlds apart, and allows each to work out its destiny under the aggregating forces, without interference from any other. Up to a certain point of condensation, which is previous to the radiation of heat into space, if this motion

were at any time stopped, it would be resolved into just the amount of heat necessary to expand the mass again to its original dimensions.

The attractive forces, gravity, chemical affinity, and cohesion, whether these forces are many or one, are inherent properties of matter. Every atom has its definite capacity of attraction, which may be exercised or not according to circumstances. For it is evident that an attracting body may be at the same time drawing toward itself a million other like bodies, or none at all, without change of its power of attraction. In like manner the magnet has a definite lifting power whether it is actually holding up a weight or not. If this attribute of matter is not operative, or but partially so, it is because heat, or motion, or some repellent force, is holding the atoms or the masses at a distance from each other, and thus opposing the exercise of it. The sum, however, of the attracting power belonging to the world of matter is as fixed as the quantity of matter itself. And I think it is in the highest degree probable that there is in the universe precisely enough repulsive force or heat to overcome all this inherent power of attraction. When all motion of the masses and of the atoms is resolved into repulsive energy, and brought to bear on the elements of matter, I imagine that they must completely fill the bounds or the infinity of space. Then, if there were perfect equilibrium or rest, no further changes or effects could ever be manifested. Such a condition, however, could probably never result from natural causes, for the time necessary to the perfect balance of the forces must be as infinite as the space through which they extend, and to "set bounds to space" has puzzled philosophy from a very ancient date. If, on the other hand, the universe of matter was created in a state of absolute rest, we have the further and necessary provision that the Spirit of God moved on the face of his creation, and thus unbalanced the forces. But the equilibrium once broken, in whatever manner, from that moment evolution must inevitably proceed. For, let there be an overbalancing of the aggregating force in ever so little or much, an equivalent of the opposing force must thereafter find some other work to do, and the field is effectually given up to the mighty agency that combines, and constructs, and brings order out of chaos.

So long and in proportion as the forming worlds continue to contract their dimensions, the rotations and revolutions increase in their velocity. Thus in the rapid and ever-speeding movements of the heavenly bodies there is stored up the ever-increasing reserve of heat that is liberated from the great contest with gravity. But in the progress of concentration there comes a time when the atoms of matter have approached each other sufficiently near for other forces of attraction, equally correlative of heat, to come into play—chemical affinity between molecules of unlike nature, and cohesion between those of like kind. Under the latter term are included all the changes of state which are the result of cooling. By these attractions heat is set free

in such abundance and under such conditions that it cannot be stored away in the motion of the masses. It is then, probably for the first time, that heat becomes a wave-force, and is radiated into space as light and radiant heat—not, however, lost, for that is impossible, but moving ever onward and outward to the day and the place of its final reclamation.

Our own solar system has already progressed far in this stage of aggregation. All the planets and satellites have become crusted over, and have ceased almost entirely to radiate heat. But the sun, the great central body, the one which should last of all become cold, is still in active combustion or chemical combination. Immense quantities of light and heat are still radiating from its surface—so immense that the little fraction which our earth catches as it flies through space gives us all the motion, and life, and beauty, which we enjoy. But the sun is not even now the glowing orb that once it was, as the rock-records of our globe testify. Its bright radiance is slowly but surely fading. Those huge, black incrustations, often twice as large as the whole surface of the earth, that float awhile on its photosphere, and then are suddenly broken up—they were not always there. And, if they have grown upon it, the uncomfortable conviction arises that they will continue to grow and darken more and more its life-giving face. Old age is certainly being written on the solar brow. It may be millions of years hence—for time is not one of the economics of Nature—but the period will surely come when light and heat will all have departed from the sun, as they once ceased to be radiated from the earth and the planets and the numerous stars that have gone out within the records of astronomy. A pall of darkness will gradually overspread the universe as one by one the stars of the firmament shall fade away and sink into gloomy, lifeless sleep. A day in the mighty calendar of creation has passed, and a night has followed, cold and dark as the tomb of expiring Nature.

But is there no awakening, no morrow to this night of the universe? Is the contest over, and never to be renewed? For answer, let us seek out in this case, as we did once before, the condition and movements of the great contending forces. Those of attraction have now in each world expended their utmost possible energy, and are holding all the forms of matter combined and compacted in a cold and rigid embrace. The forces of repulsion have entirely abandoned the contest, and are either vibrating through the unknown realms of space, or are locked up in the swift and complicated motions of the heavenly bodies. It is probable that by far the greater part of the repulsive forces thus exists in the form of motion. It has been estimated, no doubt with a near approximation to truth, that, if by any means the earth could be suddenly arrested in its rapid course, its mass would thereby be raised to the enormous temperature of 23,360° Fahr.—a heat sufficient to vaporize and dissipate every known sub-

stance. If then, as would be the case, it should fall into the sun, this heat would be increased by the fall four-hundred-fold. Now, it makes no difference in the aggregate evolution of heat whether this cessation of motion is sudden or gradual; and if we can find in Nature any agencies tending to retard the revolutions of the planetary bodies, they must inevitably sooner or later fall into the sun. In such a case it can hardly be doubted that we have found a cause sufficient to produce again the disintegration and diffusion of matter.

The wave-theory of light and radiant heat presupposes the existence of an ethereal medium pervading all space. It must be a medium of material atoms held in equipoise by a balance of forces, for it is evident there could be no wave-motion unless there was something to move, and something, too, having the attributes of matter in a state of extreme mobility or fluidity. There is no other conceivable way by which light could reach us from the sun and stars except through this all-pervading form of matter. And if there is a material medium, of whatsoever exceeding tenuity it may be, still it must present something of resistance to everything passing through it. It resists the passage of light eight minutes in 90,000,000 miles, thus proving its materiality by its resistance to force, which is one of the definitions of matter. If one could conceive of any force passing through an absolute vacuum, it could only be conceived of as passing instantaneously—there is absolutely nothing to detain it. Again, heat and its allied forces are only effects, and the subject is and can be only matter. There is no physical truth better established than that the forces can exist only where matter is in some form. It is not essential that this form of matter be subject to the ordinary laws of gravitation. The probability is, that it differs entirely from anything that we have experience of. It would seem that the atoms composing the ether of space, instead of attracting each other like those of ordinary matter, must repel each other. At least this supposition would account for what there is remarkable in connection with the ethereal medium. But, whatever theories we may adopt in regard to it, this is certainly true, that the revolutions of the heavenly bodies must be continually opening passages through it, and that a certain part of the force of those revolutions must be expended in pushing it aside. The centrifugal force is thus lessened, and the bodies are drawn nearer to the sun. In consequence, the periods of their revolutions are shortened. This has not as yet become noticeable in the case of the planets, from the fact that the slow contraction of their bulk by the loss of internal heat through volcanoes, thermal springs, and other sources, has the contrary effect of increasing the velocity of revolution, and thus counterbalancing the retardation of friction. The fact that the two effects are thus nearly counterbalanced proves the retardation, for otherwise we know that the acceleration would be observable. In the case, however, of the light cometary bodies, it has been shown that they suf-

for a very considerable retardation in their passage through space. Encke's comet formerly came regularly back into the field of the earth's orbit once in every three years, but with a period shortened six hours each time. The whole planetary regions seem to be filled with collections of matter—star-dust and meteorites. They are all revolving about the sun in eccentric orbits, and are doubtless slowly circling toward it. The zodiacal light is supposed to be only an immense aggregation of this material. Thus the thickening stratum as these strange bodies draw near to the sun shows that they are all slowly gathering to that great centre of attraction.

The evident effect of the fall of any of the planets into the sun would be the diffusion of highly-heated vapors far out into the spaces that surround it—probably far enough to reach the next outlying planet, and thereby to increase its retardation and hasten its fall into the mighty caldron. So one by one the planets dissolve and their elements fill the void of space. The expanding gases catch up the waves of radiant heat that have long been wandering from planets and suns; and the nebula is again seething and surging with its mighty contending forces. Sun-system reaches out to sun-system, and star-galaxy mingles with star-galaxy, till through all the abysmal depths matter is again "without form and void, and darkness is upon the face of the deep." Chaos has returned once more, again to be breathed upon by the Omnipotent Spirit that reforms and recreates.

ACCOUTREMENT OF A FIELD-GEOLOGIST.

By Professor GEIKIE, F. R. S.,
DIRECTOR OF THE GEOLOGICAL SURVEY OF SCOTLAND.

FIELD-GEOLOGY does not mean and need not include the collecting of specimens. Consequently a formidable series of hammers and chisels, a capacious wallet with stores of wrapping-paper and pill-boxes, are not absolutely and always required. Rock-specimens and fossils are best collected after the field-geologist has made some progress with his examination of a district. He can then begin to see what rocks really deserve to be illustrated by specimens, and in what strata the search for fossils may be most advantageously conducted. He may have to do the collecting himself, or he may be able to employ a trained assistant, and direct him to the localities whence specimens are to be taken. But, in the first instance, his own efforts must be directed to the investigation of the geological structure of the region. The specimens required for his purpose in the early stages of his work do not involve much trouble. He can detach them and carry them off as he goes, while he leaves the full collection to be made afterward.

It is of paramount importance that the field-geologist should go to his work as lightly equipped as possible. His accoutrements should be sufficient for their purpose, and eminently portable. You may judge of the portability which may be secured when I tell you that I have on my person at this moment all the instruments necessary for carrying on a geological survey, even in the detailed manner adopted in the Geological Survey of this country. You observe, therefore, that a fully-equipped field-geologist need not betray his occupation by any visible implement. The want of such tokens of his craft often greatly perplexes rustic observers, to whom his movements are a fruitful source of speculation. I shall divest myself of my accoutrements one by one as I have occasion to refer to them, and describe their uses.

The *hammer* is the chief instrument of the field-geologist. He ought at first to use it constantly, and seldom trust himself to name a rock until he has broken a fragment from it and compared the fresh with the weathered surface. Most rocks yield so much to the action of the weather as to acquire a decomposed, crumbling crust, by which the true color, texture, and composition of the rock itself, may be entirely concealed. Two rocks, of which the outer crusts are similar, may differ greatly from each other in essential characters. Again, two rocks may assume a very different aspect externally, and yet may show an identity of composition on a freshly-fractured internal surface. The hammer, therefore, is required to detach this outer deceptive crust. If heavy enough to do this it is sufficient for your purpose; any additional weight is unnecessary and burdensome. A hammer, of which the head weighs one pound or a few ounces more is quite massive enough for all the ordinary requirements of the field-geologist. When he proceeds to collect specimens he needs a hammer of two or three pounds, or even more, in weight, and a small, light chipping-hammer to trim the specimens and reduce them in bulk without running a too frequent risk of shattering them to pieces.

Hardly any two geologists agree as to the best shape of hammer; much evidently depending upon the individual style in which each observer wields his tool. This (Fig. 1.) is the form which, after long experience, we have found in the Geological Survey to be on the whole the best. A hammer formed after this pattern combines, as you observe, the uses both of a hammer and a chisel. With the broad, heavy, or square end, you can break off a fragment large enough to show the internal grain of a rock. With the thin, wedge-shaped, or chisel-like end, you can split open shales, sandstones, schists, and other fissile rocks. This cutting or splitting edge should be at a right angle to the axis of the shaft. If placed upright or in the same line with the shaft, much of its efficiency is lost, especially in wedging off plates of shale or other fissile rocks.

A hammer shaped as I recommend serves at times for other than

purely geological purposes. On steep, grassy slopes, where the footing is precarious, and where there is no available hold for the hand, the wedge-like end of the hammer may be driven firmly into the turf, and the geologist may thereby let himself securely down or pull himself up.

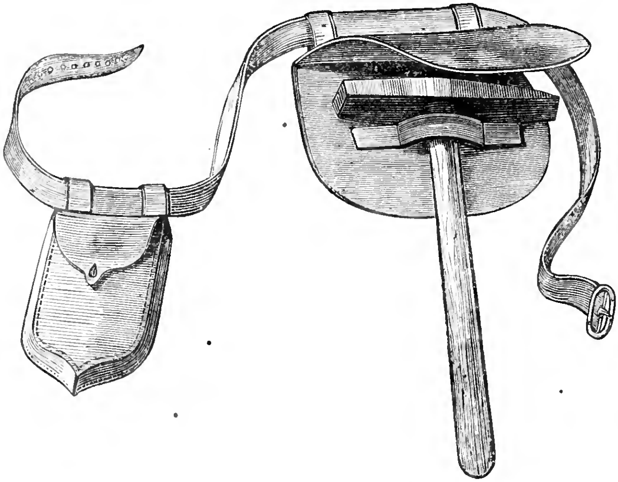

Fig. 1.—Geological Hammer, Compass-Case, and Belt.

The most generally convenient way of carrying the hammer is to have it in a leather sheath suspended from a waist-belt. The hammer hangs at the left side under the coat, the inside of which is kept from being cut or soiled by the protecting outer flap of the sheath. Some geologists prefer to carry the belt across the shoulders outside, and the hammer suspended at the back. Others provide themselves with strong canvas coat-pockets and carry the hammer there.

Even the most sharp-sighted observer is the better for the aid supplied to him by a good magnifying-glass. For field-work a pocket *lens* with two powers is usually sufficient. One glass should have a large field for showing the general texture of a rock, its component grains or crystals, and the manner of their arrangement; the other glass should be capable of making visible the fine striæ on a crystal, and the minute ornament on the surface of a fish-scale or other fossil organism. Applied to the weathered crust of a rock, the lens often enables the observer to detect indications of composition and texture which the fresh fracture of the rock does not reveal. It sometimes suffices to decide whether a puzzling fine-grained rock should be referred to the igneous or the aqueous series, and consequently how that rock is to be colored on the map.

Any ordinary pocket-*compass* will suffice for most of the requirements of the field-geologist. Should he need to take accurate bearings, however, a small portable azimuth compass will be found useful.

This is the instrument employed in the Geological Survey. It is carried in a leather case, or pocket, hung from the waist-belt on the side of the body, opposite to the hammer (Fig. 1). The directions of the dip and strike of rocks, the trend of dislocations and dikes, the line of boundaries, escarpments, and other geological features, are observed accurately, and noted on the spot at the time of observation, either on the map or in the note-book. A convenient instrument for light and rapid surveys, or reconnaissances, combines the compass and the next instrument I have to describe—the clinometer. I shall refer to it again.

The *clinometer*, or dip-measurer, is employed to find the angle at which strata are placed to the horizon—an important observation in the investigation of the geological structure of a country, and one having frequently a special economic value—as, for instance, when it points out the depth to which a well or mine must be sunk. Various patterns have been proposed and used for this instrument. Formerly a spirit-level was commonly employed. But, apart from the difficulty of rapid adjustment for the requirements of the field, the spirit-levels in the clinometers were apt to get broken. A much more portable and serviceable form of clinometer may be made by the geologist himself. It consists of two thin leaves of wood, each two inches broad and six inches long, neatly hinged together, so as to open out and form a foot-rule when required (Fig. 2). On the inside of one of these leaves a small brass pendulum is so fixed that when it swings freely and hangs vertically it forms an angle of 90° with the upper edge of the leaf to which

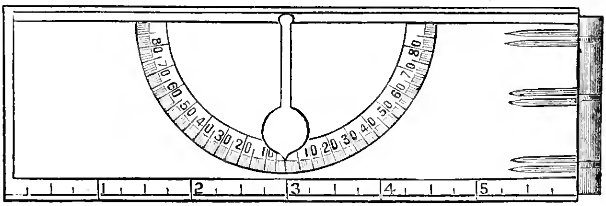

FIG. 2.—THE CLINOMETER.

it is attached. An arc, graduated to 90° on each side of the vertical, is drawn on the wood, or on paper or brass fastened to the wood, so that when the leaf is moved on either side the exact number of degrees of inclination is shown by the pendulum on the graduated arc. The corresponding face of the opposite leaf is hollowed out just enough to let the two leaves fit closely, and keep the pendulum in its place when the instrument is not in use. This form of clinometer, made of boxwood and bound with brass, may be obtained of instrument-makers. It is light and strong, and its durability may be understood from the appearance of the instrument which I hold in my hand,

and which, though it has been in constant daily use for more than twenty years, is as true and serviceable as ever.

If at any time the geologist has occasion to lighten his equipment for some long mountain-expedition, where every additional ounce of weight begins to tell by the end of the day, and where, therefore, for the sake of doing as much and holding out as long as possible, he should carry nothing that is not absolutely needful for his purpose, he may advantageously combine the pocket-compass and clinometer in the one instrument to which I have already alluded. This convenient instrument is about the size of an ordinary gold watch. It consists of a thin, round, flat, metal case, shaped like that of a watch, and covered either with a common watch-glass, or, still better, with a flat disk of strong glass. Instead of figures for the hours and minutes, the white enameled face of this geological watch is that of a common pocket-compass. But the interval between each of the four cardinal points is divided into 90°. On the central pivot, just underneath the needle, a small brass pendulum is placed, and a straight-edge of metal is soldered on one side of the outer rim of the watch-case in such a position that the instrument will stand on it if need be, and the pendulum will then point to zero. A simple piece of mechanism passing through the handle enables the observer to throw the needle off the pivot, or let it down, as he may require.

As it is impossible for a field-geologist to remember the details of all the observations he makes on the ground, or to insert them on a map, he regards a good note-book as an essential part of his apparatus. From the nature of his work, he has frequently occasion to make rough sections, or diagrams, and, if possessed of the power of sketching, he has abundant opportunity of aiding the progress of his researches by jotting down the outlines of some cliff, mountain, or landscape. Hence, his note-book should not be a mere pocket memorandum-book. A convenient size, uniting the uses of a common note-book and a sketch-book, is seven inches long by four and a quarter inches broad. Let me remark, in passing, that perhaps no accomplishment will be found so useful by the field-geologist as a power of rapid and effective sketching from Nature. If he has this power in any degree, he ought sedulously to cultivate it. Even though he may never produce a picture, he can catch and store up in his note-book impressions and outlines which no mere descriptions could recall, and which may be of the highest value in his subsequent field-work. This is true of ordinary detailed surveys, and still more of rapid reconnaissances, which may have their ultimate usefulness enormously increased if the observer can seize with his pencil and carry away the forms of surface as well as the geological relations of the region through which his traverse lies.

As every device which saves labor and time in the field, or which adds to the clearness of the work, is deserving of attention, I would

refer here to the use of variously-colored *pencils* for expressing at once, upon map or note-book, the different rock-masses which may occur in a district. Water-colors are, of course, ultimately employed for representing the geological formations on the finished map. But a few bits of colored pencils carried in his pocket save the geologist much needless writing in the field. To a red dot or line he attaches a particular meaning, and he places it on his map without further explanation than the local peculiarities of the place may require.

This leads me to remark, also, that he necessarily adopts a system of signs and contractions on his map, not only to save writing, but to prevent the map from being so overcrowded with notes as to become hopelessly confused. Every field-geologist insensibly adopts contractions of his own. For the fundamental facts of geological structure, however, it is eminently desirable that the same signs and symbols should be used with the same meaning on all published geological maps. The subjoined diagram (Fig. 3) shows some of the signs used on the maps of the Geological Survey of Great Britain and Ireland.

Such are the few prime instruments required in field-geology. We may add others from time to time, according to the nature of the work, which in each region will naturally suggest the changes that may be most advantageously made. A small bottle of weak hydrochloric acid, carried in a protecting wooden box, or case, is sometimes of use in testing for carbonates, particularly in regions where rocks of different characters come to resemble each other on their weathered surfaces. When Sir William Logan was carrying on the survey of the Laurentian limestones of Canada, he received much help from what he called his "limestone spear." This was a sharp-pointed bit of iron fixed to the end of a pole or a walking-stick. He enlisted farmers and others in his operations, instructed them in the use of the spear, and obtained information which gave him a good general notion of the distribution of the limestone. The spear was thrust down through the soil until it struck the rock below. It was then pulled up, and the powder of stone adhering to the iron point was tested with acid. If, after trying a number of places all round, the observer uniformly obtained a brisk effervescence when the acid drop fell on the point of his spear, he inferred that the solid limestone existed below, and noted the fact on his map accordingly.

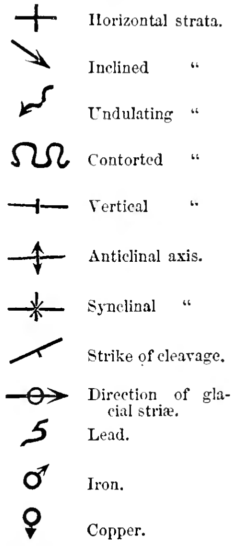

Fig. 3.—Some Useful Signs in Geological Surveying.

When the Geological Survey was busy with the great Wealden area of the southeast of England, my colleagues used what they nick-

named a "geological cheese-taster." It was, indeed, a kind of large cheese-taster, fixed to the end of a long stick. This implement was thrust down, and portions of the subsoil and of the clays or sands beneath were pulled up and examined. Similar devices must obviously suggest themselves according to the nature of the work in different districts and countries.

In the course of his observations in the field, the geologist will meet with rocks as to the true nature of which he may not be able to satisfy himself at the time. He should in such cases detach a fresh chip from some less weathered part of the mass and examine it further at home. The detailed methods of investigation, which may be pursued with all the conveniences of a laboratory in town, are not possible to him in the country. But he may subject his specimens to analysis in two cases, and obtain valuable, and perhaps sufficient, information as to their characters. He can easily fit up for himself a small and portable blowpipe-box, a machine for slicing and preparing rocks, minerals, and fossils, for examination under the microscope, and a microscope.

The *blowpipe-box* should contain a common blowpipe, platinum-tipped forceps, platinum wire, small bottles with the ordinary reagents, and as many of the most useful parts of blowpipe apparatus as the space will admit, consistently with the whole box being easily packed into a portmanteau. By means of the blowpipe, it is often possible to determine the nature of a doubtful rock or mineral, and to ascertain the proportion of metal in an ore. A young geologist should take with him to the field only the most essential apparatus and reagents; he will gradually come to see by practice what additions he may best make to his equipment.

A convenient and portable form of the *rock-slicing machine* is sold by Fuess, of Berlin. Where it cannot be obtained, the field-geologist may succeed in preparing his slices by chipping thin splinters from the rock and reducing them upon a grindstone or whetstone. One side of the splinter is to be made as smooth and free from scratches as possible, which can be effected by polishing on a water-of-Ayr stone. This polished side is then cemented with Canada balsam to a piece of plate-glass. When quite firm, the upper side of the stone is ground down until the requisite degree of transparency is obtained. Considerable practice may be required, and many preparations may be spoiled, before the observer becomes proficient. But the labor is well bestowed, for in no other way can he obtain the same insight into the internal texture and arrangement of the rocks with which he is dealing. He sees what are the component minerals of a rock, and how they are built up to form the mass in which they occur. He likewise can detect many of the changes which these minerals have undergone, and he thus obtains a clew to some of the metamorphic processes by which the rocks of the earth's crust have been altered.

The *microscope* should be, like the rest, as portable as possible. For most geological purposes high powers are not required, consequently a small microscope is sufficient.

It is sometimes of service, when working in a district where microscopic rock-sections are required, to carry a small collection of microscopic slices of selected or typical rocks or minerals for purposes of comparison. A series of fifty or one hundred slices can be packed in a box a few inches square.—*Outlines of Field-Geology.*

ON THE ANNIHILATION OF THE MIND.

By JOHN TROWBRIDGE,

ASSISTANT PROFESSOR OF PHYSICS, HARVARD COLLEGE.

THERE are some subjects which are unapproachable by any of the present methods of scientific investigation, yet the human mind, especially that form of it which is utterly untrained in scientific methods of thought, loves to ponder over the profoundest mysteries, and calls upon Science with an almost imperative tone to solve moral doubts and fears. One of the greatest questions which one finds is perplexing the general reader of popular science, who is also an independent thinker on religious questions, is that of the survival, so to speak, of the human mind and all that betokens the mental and moral power of man after death. The alarming doctrine that the mind and soul are the result of a process of growth in the individual, like physical growth of bone and muscle, and that body and mind increase and decrease together, and are resolved into the elements again at the close of life, is not infrequently put forward by materialists. It is maintained, further, that the belief in immortality is largely a matter of education, notwithstanding the evidence which is brought forward to prove that even uncivilized nations have a belief in deities and a future life. To the materialist, the picture presented by the unwrapping of a Peruvian family burial-sack, with its young and old mummies, and its collection of pottery and bag of grain to help the disembodied spirits on their way to a happier hunting-ground, is pathetic only because it seems a hopeless superstition. What kind of a soul, it is asked, has the Digger Indian who is hardly more intelligent than a wild animal? If he has a mind and soul, so has my dog. No; what we call the soul is a cultivated state or condition which perishes like a highly-disciplined adaptation of the muscles of the body which a gymnast possesses. It is a state of crystallization; it is a reaction or interaction of atoms consequent upon physical growth. When the body dies, the mind and its attributes perish. Such utter disbelief in the great doctrine of the resurrec-

tion is hard to combat; for, even among scientific thinkers, the class of men who do not become attached to the cast-iron ways down which thought has traveled to them is small. A logician who sets his mental machinery in motion, and then steps to one side to scrutinize its defects and limitations, is rare. To hint that there may be higher processes of logic than those generally accepted, implies the possession of a scientific mind, to say the least, not of a quantitative cast. It has seemed to the writer that a discussion of the idea of the degradation of spiritual energy, so to speak, would not be an unprofitable or irreverent subject from the purely scientific point of view. A little thought will convince one that no transformation of energy can take place in Nature without degradation or dissipation of it. In order to generate steam we must expend the energy stored up in the coal; and in its turn the steam in doing work passes from a hotter state to a colder one. A fresh supply of energy is needed in order to enable the cold body to do work again. There is a tendency to a uniform diffusion of heat, or to a degradation of energy.

In the process of physical growth and decay, the doctrine of the conservation of force, and the degradation of energy, is clearly exemplified. What the body receives from the sun in the process of growth is given back, transformed, to the earth. At death the physical being undergoes a chemical change; and the earth and air recall to themselves their respective portions. Here there is an equivalent rendering of matter. If the soul and mind have been the result of a process of growth, the entire potential energy of the living unit has not been accounted for in the final dissolution. The song of a bird can be resolved into waves of motion which, although they cease after a moment, and the consequent vibrations of the human ear die away, are still exerting an influence upon matter. Babbage, in his "Bridgewater Treatise," has drawn a powerful picture of the possible permanence of the motion which has been communicated to the ether by the tones of a human voice, and shows that it may not be impossible to believe that the eloquence of Demosthenes still continues in some form of motion. So we can believe that the physical effects of a bird's song can remain forever impressing some form of motion upon matter. Besides the physical vibrations which the song communicated to the human ear, it has so impressed the mind that, after the lapse of years, the repetition of the same notes can call up innumerable memories of deeds and a thousand pictures of the past. In the mind of the poet it may be the one detached note from which he can construct a song of home which can serve to arouse the ardor of the Christian Slav against the Turk, and store up a fearful potential energy which by its fall can destroy entire nations. Here we have, in the transformation of the vibrations of sound to another form of energy, a continual degradation of energy; but we may have by the same means an exaltation of spiritual potential energy which is unexplained

by our doctrine of the conservation of force, and seems to require the incoming of another element in our calculations. Where does appear the force of mind, the high courage, which can enable a feeble body to maintain a high potential energy out of the same physical materials which contribute to the formation of the sluggishness of others? It may be answered: What makes the difference between the energy of the blooded hunter and that of the dray-horse? Where does the difference appear in the final dissolution? With this latter question we immediately perceive the difference between the degradation of energy which accompanies that which recalls life, and that which is manifested in the combinations of matter. Gunpowder, fired by the concentrated rays of the sun, leaves only ashes and a rapidly-disappearing veil of smoke. It has impressed upon the ether vibrations which are forever undergoing rapid transformations. In regard to its physical nature it goes from inertness to inertness. A current of electricity is maintained by chemical action which takes place in a voltaic cell. As long as this action continues, the current can exercise its functions. When the potential energy of the chemical activity falls, the current dies away. From the earth the gunpowder can be reconstructed with exactly the same characteristics. From the earth beings endowed with life can be created by a process which is far beyond our ken, yet the new creations are never exact reproductions. We are forced to acknowledge that there must be something which is called the principle of life. If there is such a principle, does it die at the physical death of each individual? If so, we must modify the all-embracing scope of the doctrine of the conservation of force and its non-annihilation. When a body loses its heat, or its electrical charge, we can readily form the equation of transformation. With matter endowed with life we must join, by an additive or subtractive sign, an unknown function which we may term the life-function. In discussing such an equation of transformation of energy, we must refuse to admit such a term depending on the life-function, on the ground that we are dealing with matter and material forces, and that there is no energy distinct from that communicated by chemical processes. Or we must admit it; and make some assumption which can just as well be made in reference to its spiritual or non-physical nature as in regard to the peculiar relations which different organic compounds may maintain toward each other. The first step leaves an hiatus in our expression for the transformation of energy, and the second gives a choice of belief.

It may seem to some that the doctrine of Darwin is capable of being extended to intellectual philosophy; and, as certain animal types fail to flourish and perpetuate themselves because the conditions are not propitious, so we can admit the possibility that the South-Sea cannibal is endowed with a mind or soul germ which could be developed if the right conditions were at hand. In chemistry we

find many substances which are apparently identical in composition, but which possess diverse qualities. Certain conditions are requisite to produce different states of the same compound. If these conditions are not fulfilled, the required combination is not made. With the cannibal our equation of the conservation of force would require a small term to represent the mind and soul, but a comparatively large one, it may be, to account for that stress of the particles, so to speak, which manifests itself as life. The source of the physical energy is the sun's heat. Looking, therefore, at the problem of life and mind from a purely scientific point of view, we seem to require a source from which can come the principle of life, and which can create moral and intellectual growth in suitable soil and under fitting conditions. In the case of the energy derived from the sun's heat we have a cycle of operations in which there is no annihilation of force. If we grant that there is a source of life and mind independent of mere chemical change produced by the sun's heat, and if we adhere to the notion of the conservation of force applied to this principle of life and mind, we are led to adopt the idea of a cycle of operations in which there is no annihilation of spiritual force. The doctrine of the existence of the spirit after physical death seems to me not to be foreign to the scientific ideas of the conservation of force, which have now obtained such complete supremacy in the science of physics; or to the doctrines of Darwin, which are accepted by so large a body of eminent naturalists. Without the sun there would be an annihilation of force. When energy is dissipated, we find the sun exalting it again by processes which we cannot completely follow. The idea of a great source of life and mind, the prototype of our physical sun, which sets in motion a vast scheme for the survival of the fittest, and the exaltation of energy in vast cycles, is not inconsistent with the doctrine of the New Testament, and seems to be required in a philosophical theory which shall endeavor to account for the differences in that great spiritual world which are continually suggested to the human mind by the various types of mental growth.

THE FIRST "POPULAR SCIENTIFIC TREATISE."

By Professor S. P. LANGLEY,

OF THE ALLEGHENY OBSERVATORY.

SOME one has said that there is nothing in all the world of commonplaces which was not once a novelty, and born from the conception of an original mind. The idea that science is not for the professional student only, but that every one will take an interest in its results if they are only put before the world in the right way—this notion which has now produced a literature of its own—even

this idea was once brand-new. At the present time, when the most recondite investigation is summarized and explained for the unscientific, so that what is capable of translation into common speech is discussed at tea-tables within a week after presentation, it is not easy to go back in imagination to a day when the student of Nature worked only for, and was judged only by, a narrow circle of his own, and most gentlemen and gentlewomen were not only completely ignorant of scientific thought and method, but would have felt in danger of acquiring pedantry in learning them. Such, however, was the state of things two hundred years ago in the then most cultivated society of Europe; and it was to Bernard le Bovier de Fontenelle that first presented itself the audaciously novel conception of writing a book which should render some of the results of science into a language comprehensible by the most fashionably ignorant, and in a style which should make science itself recognized as a permissible topic of discussion in the *salons*.

His happy thought was executed with a cleverness akin to genius: the book went into all languages, and is said to have been reprinted a hundred times during the last century. "Conversations on the Plurality of Worlds" was its title; and though it is by no means rare, and indeed remains a classic in its kind, it is probably nowadays known only by name to the majority of English readers. Yet, in its way, nothing better has been done since, or rather its way is one which has had no entirely successful imitator among all its numerous progeny. It will be interesting, then, to look at this original in a path since so well trodden, and in doing so it may be premised that the book appeared in 1686, and was addressed to such a circle of readers as then only French society and the court of Louis XIV. could furnish. The age of Corneille, Molière, and Racine, La Bruyère, La Rochefoucauld, and St.-Simon, Bossuet, Massillon, and Bourdaloue (and it might be added of Fontenelle himself), was certainly not devoid of literary culture, and yet that very culture had so completely excluded science that we shall presently see the marchioness, who is presented to us as a type of accomplished elegance, expressing complete astonishment at hearing that the earth turns round, and the most *naïve* wonder at the idea that her park and castle, and she herself, are actually turning too!

The "Conversations" are introduced with a description of a moonlight night in the park, where the author is walking with the marchioness, to whom he is paying his court, with the accompaniment of perpetual and somewhat insipid compliment, which seems to have been a part of the conversational dress of the time, and to have belonged to the fashion of the period as much as its lace-covered waistcoats.

The talk is first of the beauty of the night, and moves on in an easy and natural tone, till the author casually speaks of the stars they are contemplating as "these worlds." The lady asks for an explana-

tion, and, on being told that it is likely to prove too learned to amuse her, only insists the more on the perfect capacity of her sex for the reception of the most philosophic ideas, and demands a lesson on the stars at once.

"No!" replies Fontenelle, "never shall it be said of me that in a wood, at ten o'clock at night, I talked philosophy to the most charming person of my acquaintance. Seek your philosophers elsewhere!"

But it is vain for him to try to bring the conversation back to its former channel, and to represent how much better it would be to talk nonsense, "as any reasonable people would do in our place"—he has to yield; but the dialogue, often very lively, is represented through the book as carried on by the gentleman with the wish to pay his court under cover of talking science; while the lady is ever on the alert to call him back to his ostensible theme when she finds him trying to wander from it. We must perforce omit this in giving only a part, and that chiefly Fontenelle's; but even in teaching he will be found anything but dull. As his pupil is as ignorant as she is intelligent, he begins at the beginning:

"All philosophy, I said, is founded on two facts, that we have curious minds and poor eyes, for if your eyes were better you might see for yourself if the stars were suns lighting other worlds, or if, on the other hand, you felt less curiosity, you would not care to learn, which would come to the same thing; but everybody wants to know more than he can see, and there is the difficulty. If we could even see unmistakably what we see at all, that would be something gained, but we see quite wrongly, and so your true philosophers pass their lives in the unenviable condition of doubting what they do see, and trying to divine what they cannot. I always think of Nature as a great spectacle, something like the opera. From your opera-box you do not see the theatre quite as it really is, for the scenes and stage-apparatus are arranged for effect at a distance, and they keep the weights and wheels which put all in motion out of your sight. Naturally, you do not pay much attention to the principle on which all this works. But then, again, there may be a machinist down by the orchestra, who is puzzled by some stage-flight, which is unaccountable to him, and who feels that he must find out how it was done.

"The machinist, you observe, is something like the philosophers; but what makes the difficulty worse for *them* is, that in Nature's machines the cords are all hidden—hidden so neatly that people were a long time conjecturing as to what caused the movements of the universe. Just imagine, for instance, Pythagoras, and your Platos and Aristotles, at the opera—they and all their kind whose names are in such reputation. Suppose that they saw the representation of Phaethon borne off by the winds, that they could not discover the cords, and did not know what lay behind the scenes. One of them" (the author is here giving us samples of the philosophy still current

in his time) "says, '*Phaethon is carried up by a hidden principle;*' another, '*Phaethon is composed of certain numbers which make him rise;*' another, '*Phaethon has a certain attraction toward the top of the theatre;*' and a hundred such vagaries, which I should have supposed would have cost antiquity all its credit. Finally, Descartes" (an Englishman would have said Bacon), "and some other moderns, have said, '*Phaethon rises because he is drawn up by cords, and because a heavier weight descends.*' So now we have come to believe that, if a body move, it is because it is pushed or pulled, and one who could see Nature as it is would simply be seeing what is behind the scenes at the opera."

After this, Fontenelle goes on to sketch the history of his science, and thence to give an account of the Ptolemaic and other systems, which preceded the Copernican. Here, again, a happy image reminds us of a danger all system-makers share, as common partners in a weakness which is as universal as humanity:

"Before I explain the first of these systems, I beg you to remember that we—all of us—are like a certain madman at Athens you may have heard of, who took it into his head that all the ships which came into the harbor belonged to *him*. Our common failing is to believe all Nature created for our own use, and when you ask our philosophers what end is served by that host of stars, they will calmly tell you, It is there for us to look at.' In this way they could not fail to suppose that the earth was fixed in the centre of the universe, and that all the heavenly bodies were set to revolve about her, and give her light; the same propensity which leads one to desire the most honorable seat at a ceremony makes the philosopher in his system put himself at the centre of the universe if he can."

It will be seen, as Sainte-Beuve remarks, that Fontenelle possesses the art of scientific *insinuation* in the highest degree; in addressing his marchioness, he is here appealing to the intelligence of every ignorant person who, rather than resemble the Athenian madman, is cajoled into truth, and disposed in advance to reject Ptolemy's system, in favor of the Copernican.

The account of the Copernican system involves the (to the marchioness) entirely novel idea of the earth's rotation. This is presented to us in a lively picture of the scene which would be offered to a spectator suspended above the surface as the speaker imagines himself to be: "'Passing under my eyes I see all sorts of faces, white, black, and brown. First come hats, and then turbans, and then shaven crowns; now towns with church-spires, now cities with slender, crescent-tipped minarets, now porcelain towers, and then again wide oceans and dreadful deserts.' 'What,' she cries, 'then in the place where we are—I don't mean this park, but this very place in the air—there are people continually passing by, who come where we are now, and at the end of twenty-four hours we get back again our-

selves!' 'Copernicus,' I replied, 'could not understand it better.'" This novel theme continues to occupy them during their return to the house, and the first evening secures her belief for the new system.

The next morning, on Fontenelle's sending to ask how the lady has passed the night, and to politely inquire whether she has been able to sleep while turning, he is assured that she has already got used to the motion, and was able to rest as soundly as Copernicus himself could have done. With so apt a scholar, progress is rapid, and, by evening, we find them discussing the habitability of the moon, and the cause of the sun's light and heat. What is the view of our author (the subsequent secretary of the Académie des Sciences, and an authority in his day) on the source of supply for this immense expenditure of the solar energy? What theory does he adopt—how was it accounted for in his time? Listen to the explanation of the man who has just satirized so happily the fallacies of the schoolmen. It shines because "it is self-luminous in its nature." And this is given in good faith by Fontenelle as a *reason!*

Clever as he is, he is here in the bondage of his age; but he might yet have taken a lesson from a contemporary, who, though pretending to no "philosophy," had seen and laughed at the weakness of the learned of his time in thus making words do duty for facts. We remember how the candidate for medical honors in the "Malade Imaginaire," on being asked why opium induces sleep, replies to the delighted satisfaction of the examining Faculty that it is because it possesses a soporific quality! When we see a man so acute as Fontenelle giving a precisely similar answer, with an obtuseness so plain to us, so imperceptible to him, can anything suggest more pertinently the need of watchfulness for traces of this legacy of ancient fallacies of thinking in our own modes of thought?

The third evening is occupied with a further discussion of the moon, and of Venus; on the fourth the other planets are considered, and reasons given for their possible habitability, some of which would hardly satisfy a more modern philosopher. Thus, the ingenious but scarcely satisfactory suggestion is made that, in spite of the neighborhood of Mercury to the sun, that planet may be a comfortable residence, owing to the presence there of large quantities of saltpetre, a substance which (according to our author) gives out "cold exhalations" in the sunshine. Lest this idea be unacceptable to our skeptical age, it should be added that Fontenelle takes care to fortify his position by citing the case of China, large portions of which, it appears, in spite of a southern latitude, experience extreme cold, even to the freezing up of their rivers in July, on account of the existence of this ingredient in their soil!

The "vortices" of Descartes are here introduced and offered as an explanation of the motions of the Jovian satellites about their primaries, and of the principal planets about the sun; and, in the next

evening, are applied to elucidate the constitution of the milky-way, in which worlds are, it seems, so thick that the plausible suggestion is made that their birds may fly from one to the other!

The remainder of the work is chiefly occupied with a description of the heavenly bodies considered with reference to their possible habitants, and here Fontenelle is not likely to be found tripping, for as to the nature, ways, and modes of living, of the inhabitants of the other planets, he is quite as well informed as we are. We shall find here nearly all that can be said, in the simple absence of any knowledge whatever on the point in question, but we may be more reasonably interested in the happiness of some conjectures offered, where he incidentally speaks of the physical constitution of the bodies he is considering. He tells us, for instance, that the rings of Saturn are supposed to be composed of numberless little moons, close together, and moving in the same orbit; an explanation which appears to have been lost sight of till modern analysis showed that they could not be continuous solids, and modern observation that they could hardly be liquid or gaseous. We have passed over too readily, perhaps, the purely speculative portion of the work, which, if not very instructive, is certainly entertaining, and filled with felicitous illustrations, such as that (too long for quotation) of the citizen of Paris, who maintains that St.-Denis, whose houses he can just distinguish from the towers of Notre-Dame, is uninhabited, because he can see no inhabitants. Or, for still another instance of this art of "scientific insinuation" already referred to, take the passage where the marchioness, after declaring herself dissatisfied with extravagant speculations about the inhabitants of the planets, is told that something positive is, after all, really known about a race on one of them, and which appears from his description to be remarkable indeed. He gives a minute, and, as he asserts, a trustworthy, account of these extraordinary beings, who he would have us believe are most laborious and skillful, yet live by pillage; who have no sex, yet increase as a nation; who subsist in the happiest concord, yet periodically put to death a portion of their innocent fellow-citizens; and so on, until the lady, who finds the story more incredible than any of the preceding speculations, on learning what the race is, and on what planet they exist, is forced to admit that truth may be stranger than fiction, and that no extravagance of his fancies about the possible commonwealths of other worlds surpasses what she has just been entrapped into listening to about that of the *bees* on our own.

Fontenelle, with all his abundant ingenuity, has one radical defect as a literary artist, and perhaps some will be disposed to add, as a student of Nature. He appears to have no power of moving or being moved by anything like emotion, or of perceiving anything not comprehensible to an intellect divorced from sympathetic intuition. The gallantry which he introduces as an element in the dialogue, and

which our citations do not undertake to illustrate, is filled, for instance, with ingenious conceits which, though falling coldly on modern ears, were considered in the happiest taste by the audience to whom the book was addressed. But they are of an artificial cleverness, and precisely what we might expect from the man who was said to have "as good a heart as could be made of brains."

Sainte-Beuve has well indicated our author's strength and weakness by comparing his clever opera-box view of Nature with that of Pascal in the majestic movement of the awe-inspired passage at the beginning of the "Pensées."[1] While agreeing to the judgment of the great critic, it may be observed, however, that, if Fontenelle be devoid of poetry, he has at least one image of a grace nearly allied to it. He has been speaking of the chances of the sun's light failing us wholly, as it is said to have partially done in the year following the death of Cæsar, and pointing out, with what seems justice, the imperfect grounds for the confidence of mankind in the constancy of Nature's action here in the future as in the past, founded as that confidence is on an experience of the human race—so long, judged by *its* life, so short in comparison with Nature's own. With a sort of pathetic sense of the fallacy, he compares this little accumulated experience of the generations of man to the traditions of some roses of a day, leaving each to its successor an account of the gardener in whom successive ages of these ephemeral flowers have seen no change. "*We have always seen the same gardener; in the memory of roses none has been seen but him; what he has ever been, that he is now: surely he does not die as we, or change.*"

Fontenelle, throughout the "Conversations," adopts the Cartesian hypothesis of "vortices" in accounting for the planetary movements, and this, indeed, he continued to cling to long after. The true theory of gravitation had been given by Newton, and obtained complete acceptance in England. His more serious work is to be found chiefly in the well-known "Éloges," which, as perpetual secretary of the French Academy of Sciences, he pronounced on its deceased associates; but it is probable that he will, nevertheless, be remembered as much by these "Conversations," which, had they no other merit, would always possess an historical interest, as opening the way to our present popular scientific literature.

We should not close this imperfect notice of them without again reminding the reader that the form of a dialogue gives the original an attraction which is necessarily missed in brief extracts, and that the plan on which they thus rest for uniting instruction and amusement (a plan which obliges the imaginary speaker to be paying his court and talking science at the same time) would have been a failure in almost any hands but those which could manage so difficult a blending, and keep as far from pedantry as from ridicule. Fontenelle's

[1] "Que l'homme contemple donc la nature entière dans sa haute et pleine majesté," etc.

gallantry, like his science, may be now a little out of date, but he manages at least to unite these two most opposite conversational ingredients in chemical union. When the lady would send him back from love-making to astronomy, he contrives to give both together, and, consistent to the close, takes leave of his charming scholar with the modest request that, as sole reward for his pains in teaching her the heavens, she will never again look on sun, moon, or stars, without thinking of *him*.

THE BALL-PARADOX.

By THOMAS S. CRANE, Mechanical Engineer.

THE exhibitors of the atmospheric air-brake, at the Centennial, attached a tube to the air-reservoir for the purpose of showing the immense pressure employed.

The current rushing from the small orifice of the tube sustains balls of varying gravities, according to the pressure applied.

Once, on accidentally resting the base from which the tube springs upon something lying on the table, it was found that, although no longer vertical, the current of air still held the ball in suspension, the ball revolving rapidly, and apparently hanging to the jet of air, which strikes the sphere at its upper side.

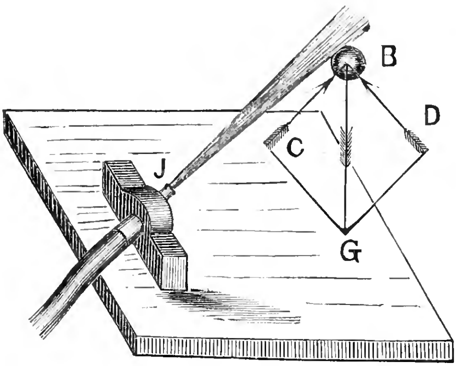

Fig. 1.

It also makes little difference in the result whether the ball be a solid glass one an inch and a half in diameter, or a hollow rubber ball, or a solid wooden one three or four inches in diameter, the only variation being the distance at which the spherical body is held from the orifice.

When a glass ball with interior colored lines, such as children play with, is gently held in the current until the air has the sphere well in its power, it will rotate partly back and forth at first, and,

when really revolved by the force of the air, has an uncertain axis of rotation until it has been turning for some time. The jet of air will also sustain a larger ball of lighter gravity behind the glass one, the former hanging on the lower side of the jet behind the heavier and smaller one.

These phenomena have excited so much attention that the following is offered as an illustration of the principles involved, and in explanation of the various points noted above:

The current of air sustains the ball by removing the atmospheric pressure from the ball where it strikes it; the unbalanced pressure of the air on the opposite side then forcing the ball toward the current, as shown by the arrow marked *D* in Fig. 1. The friction of the jet *J* against the ball tends to throw it in the direction indicated by *C*. To balance these two forces, we have the action of gravity, shown at *G*, which, being a constant factor, must be exactly neutralized by the forces named for the ball to remain suspended.

This adjustment, nice as it is, can be easily effected by placing the ball near enough to the jet at first; for, the pressure *D* being ample to sustain the ball in any position (else the experiment cannot be performed), the force of the jet will inevitably drive the ball away to a point where the power in that direction is just able to balance the force of gravity—the ball being evidently lifted, in spite of gravity, so long as it moves in the direction of the jet, and the force *C* naturally diminishing as the distance from the orifice *J* increases.

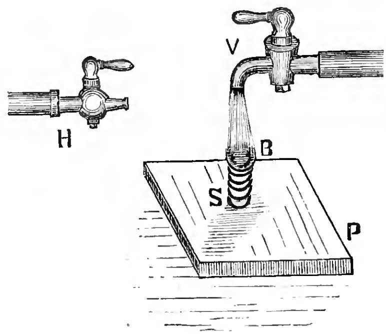

FIG. 2.

To make it clear that it is the ordinary atmospheric pressure that supports the ball, let us imagine it exposed to two forces (as shown in Fig. 2), acting on opposite sides of the sphere. The atmospheric pressures that act on all other sides of the sphere are ignored, as they perfectly balance one another.

If a ball *B* (Fig. 2) is secured to the top of a spiral spring *S*, attached to a platform *P*, and a jet of water *V* projected vertically upon it, the spring will be compressed until its resistance is equal to

the force of the jet. In that position the ball resembles a sphere exposed to atmospheric pressure above and below.

Now, let an horizontal jet of water *H* be thrown against the vertical jet *V*, as shown in Fig. 3, and its action, opposed to the spring *S*, must cease at once, and the unbalanced pressure of the spring raise the ball into the position shown in Fig. 3.

The situation of the ball in Fig. 3 is now equivalent to that in Fig. 1, where the air-jet *J*, passing over one side of the ball, calls into action the pressure *D* at right angles to the jet. Were the sphere *B* in Fig. 1 placed in the centre of the jet, no such action could result; and, if the ball were placed there, its gravity would be unbalanced until the ball fell to one side of the jet, and the supporting power of the air evoked.

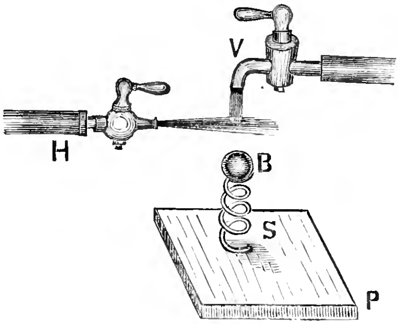

Fig. 3.

To prove that a current of air moving parallel with any surface destroys the atmospheric pressure at that point, take a visiting-card and bend the ends at right angles with the card, so as to turn up one quarter of an inch at each end. Now place the card near the edge of a smooth table, supported by the two ends like a little bench, and try the effect of blowing violently between the card and the table in a direction parallel to both. The current will destroy the atmospheric pressure beneath the card, and the unbalanced pressure above will force the middle of the card downward. Or, take another card and fit a quill or straw tightly into a hole cut in the centre. Try to displace another card laid loosely over the first by blowing upward against it. If a pin is stuck through the centre of the second card, into the opening of the quill, to keep it from sliding off, it will be found that no effort will blow the upper card from the first, as the current of air passing out between the cards destroys the atmospheric pressure between them, calling into play a force upon their outside surfaces that presses them tightly together. The arrangement of the cards is shown in Fig. 4.

It is thus evident that a pressure perpendicular to any surface can be displaced by one acting parallel to it.

An experiment illustrated in Fig. 5, and successfully performed while writing these lines, will settle all doubts, if any remain, upon this puzzling point.

Attach a pith-ball to a short piece of thread, and, knotting the other end, slip the knot in a slit in one end of a quill so as to secure it firmly, and retain the ball about an inch from the other end of the

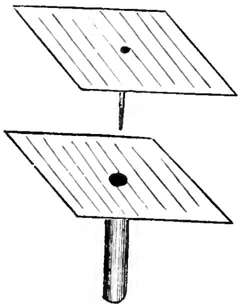

FIG. 4.

quill, as shown in Fig. 5. Now blow through the quill *Q* steadily, and the ball *B* can be made to hang from or upon the under side of the jet *J*, being prevented by the string *S* from blowing away, and the atmospheric pressure *A* balancing the gravity *G* of the light ball.

As the atmosphere presses nearly fifteen pounds upon a square inch, a ball one-quarter of a pound in weight would be balanced by the full pressure of the air upon a surface only $\frac{1}{60}$ of an inch in area. It remains to notice the rapid revolutions of the ball and its uncertain axis of rotation when first suspended in the jet.

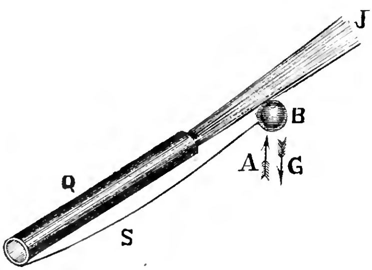

FIG. 5.

Few balls being perfectly round, or of uniform density, will revolve on their own centres under such conditions, but on the shortest axis passing through their centre of gravity (seldom the centre of form).

It is easy to show that all bodies freely suspended tend to revolve on their shortest axis, by tying a string a yard long to a door-key, just under the head, so that it will hang nearly vertical. If the string

be now rapidly twisted by the thumbs and forefingers of both hands, the key will assume an horizontal position, and the string revolve in the form of a cone.

The friction of the jet must, therefore, tend to rotate a ball on an axis at right angles to the path of the jet, and, if this axis is not the shortest one passing through its centre of gravity, several oscillations, back and forth, must occur before the necessary adjustment is made.

When two balls of different densities are sustained by the same jet, it seems plain that each is sustained by the pressure of the air on the side opposite to the contact of the jet, for it is evident that, farther from the orifice, the jet has less power to displace the atmospheric pressure, and at that point the lighter ball only can be sustained.

In its rapid revolutions in such a jet of air as we have described, a light and hollow India-rubber ball affords a beautiful illustration of the flattening of the earth's poles by its revolutions on a free axis.

LABORATORY ENDOWMENT.

By F. W. CLARKE,

PROFESSOR OF PHYSICS AND CHEMISTRY IN THE UNIVERSITY OF CINCINNATI.

THE advancement of science is at once a glory and a disgrace to our modern civilization. It is glorious that so much has been done, but disgraceful that the public should be so often indifferent to the doing. In view of the benefits derived from scientific research, it would seem as if governments and communities ought to vie with one another in its encouragement. But, as a matter of fact, this assistance has in every country been unsystematic, meagre, partial, and infrequent. A museum may be equipped, perhaps, an exploring expedition fitted out, a geological survey established, or a party of astronomers sent forth to observe an eclipse or transit. Even these things are too often done grudgingly, and on a basis of false economy. Physics and chemistry, the two sciences most immediately bound up with modern progress, have received little or no public aid. No laboratory exclusively for research has yet been endowed either by national or private enterprise. Colleges enough have been founded, with laboratories more or less fitted for the work of routine instruction; but these are manifestly unsuited to the production of remarkably far-reaching results. Every great industry in America has been directly benefited either by one or the other of the two sciences in question; fortunes have been made from practical applications of their principles, and yet scarcely anything has been done for them in return. It would seem as if our manufacturers expected to get applications of science without any science to apply. Nearly all

the research accomplished, either in our own country or in Europe, has been done by university or college professors, in the intervals between their regular duties, as an incidental matter, and usually with meagre appliances. Two results have followed: first, much wasting of individual energy; and, secondly, a lack of coherence in the knowledge won. The data of science become unsystematic, scattered, full of gaps and breaks, more like an archipelago than a continent. A thousand investigators, working independently and with but casual reference to each other, may discover a vast number of important facts, advance many useful arts, and yet accomplish but little for definite, exact, systematic, coherent science. The world gains much by their labors, but only a tithe of what it might gain were those labors wisely aided and fostered. For the present state of affairs, however, nobody is to blame. It is probably an unavoidable incident of scientific growth. A wider public culture and a deeper public appreciation will undoubtedly correct it. Looking forward hopefully, then, we may ask how the greatest good is to be done.

That the two sciences already mentioned are much in need of material encouragement, there can be but little doubt. They are experimental sciences, requiring for their advancement expensive apparatus and materials, such as individual students cannot provide for themselves, or few universities supply. Other branches of knowledge have been better provided for. Every observatory is to a certain degree a laboratory for astronomical research; every well-arranged museum affords opportunities for the scientific naturalist; every geological survey is ostensibly an organization of investigators. But a college laboratory, full of elementary students, each calling for personal attention from the professor, can hardly supply the best means for really advanced work. To be sure, every professor ought to do something, if only to discover a single small fact a year. Even though that fact be a hopeless negative, it will still have a true scientific value. When we question Nature, every answer, whether yes or no, counts for something in the upbuilding of science. Every man who is fit to teach science at all is competent to do at least a little in this direction. A little also may be accomplished by students; such work, for example, as the determination of densities, or completing the description of simple compounds. In one laboratory special attention might be paid each year to a single class of not over-complicated substances; and the advanced students could for that class fill up some of the gaps in our knowledge. But this work, although of immense value to science, is not of the very highest order. The most important labors can scarcely be undertaken save in laboratories specially and liberally endowed for purely scientific research.

The objections which are frequently urged against the endowment

of research arise from a misconception of what is really intended. It is ordinarily assumed that such endowments would merely provide large salaries and abundant leisure for certain scientific men, who, with no clearly-defined duties, and no distinct relation to each other, should try experiments at their own sweet will, and make discoveries whenever luck and chance were favorable. Such a vague plan for aiding science would of course be objectionable. Not only might the so-called "young men of promise" become deprived of energy by the ease of such positions, but even experienced workers would be liable to regard their salaries as the means of comfort without hard labor, or as a reward for past achievements. The money thus expended might advance science a little, but probably not so much as if it were paid over to some first-rate college or scientific school. Science is not to be truly encouraged by the creation of mere sinecures for scientific men. To construct an argument, however, against such a plan as the one mentioned, would only be to demolish a very clumsy man of very coarse straw. A true laboratory for research is something quite different from the feather-bed institution commonly objected to.

That there should be facilities for research, and that the investigator deserves a livelihood, nobody will deny. Indeed, these two points form an almost conclusive argument in favor of the endowment of laboratories. There is yet another consideration of very great force with which the public mind is less familiar. Both in chemistry and in physics there are many unsolved problems too great for individual students to grapple. Their solution can be effected only by the coöperation of many trained specialists, working harmoniously together upon the basis of some definite plan. The fundamental principles of physical science, principles upon which rest many applications important in the arts, and in which every manufacturer has a direct although too frequently unconscious interest, are to be eventually based upon the answers to these problems. In many a branch of industry thousands of dollars have been spent upon scientific experiments, which, for want of fundamental principles, have been aimless and unsystematic. Mere tentative trials, costly and laborious, with almost even chances for and against success, have taken the place of rigorous, careful, strictly scientific work, based upon definite and certain foundations. In short, the arts have suffered from the fact that neither chemistry nor physics can yet claim to be really an exact science. The question of the endowment of research, then, may well be put in this shape. Laboratories should be established in which adequate corps of thorough specialists shall coöperate in those investigations which individuals cannot undertake.

In a laboratory organized upon this idea, every worker should be assigned to definite, positive duties, the accurate and careful performance of which would eventually be sure to advance exact knowledge.

Here there is nothing speculative or doubtful. Here are certain things to be done, which can be done only by men of the most thorough training, equipped with the best appliances. In such a laboratory, chance would have but little place. The work would run to hard routine, to the solid establishment of accurate scientific data, to the systematic determination of substantial facts. Precise physical measurements would precede generalization, just as the labor of the quarryman goes before that of the builder. Startling and brilliant discoveries might possibly be made, but incidentally rather than as the result of special effort. The real value of the institution would be independent of anything sensational, and would rest upon considerations of the most severely practical kind.

Examples of the sort of work appropriate to an endowed laboratory may easily be found. For instance, one of the greatest of all scientific problems is that of the connection between the composition of a substance and its physical properties. Suppose this question were to be taken up systematically by a well-organized body of investigators. The first step in the research would manifestly be to determine, carefully and with the utmost rigor, the physical properties of the so-called chemical elements. At the outset each one of these substances would have to be isolated in quantity, and in a chemically pure condition—a labor which of itself would involve a great amount of research. Some of the elements have never yet been seen in a state of absolute purity, or have been obtained only in very minute portions, and accordingly new methods of treatment would need to be devised. Then would come the measurement of physical relations, thermal, electrical, optical, magnetic, mechanical, and so on. For each element, as far as possible, should be determined the melting-point, the boiling-point, the density, the coefficient of expansion, the specific and latent heat, thermal and electrical conductivity, the thermo-chemical constants, and many other data of much importance and value. Furthermore, these constants should be determined under widely-varied conditions, notably of pressure and temperature. For example, it would be necessary to ascertain the coefficient of expansion, and also the specific heat of a body at every degree, through a wide range of temperatures, and in not merely one, but in several series of observations. Thus, and thus only, could we attain to the exactness which science rigidly demands. Besides the actual measurements, this great labor would in many cases involve the comparative testing of various methods of research, and in some instances the invention of new experimental processes.

Years could be spent upon the metals alone, and the work done would add not only to our knowledge of their properties, but also much to science as regards variety and precision of methods. In connection with these researches would naturally arise an investigation of metallic alloys—a subject of which true science knows as yet

very little. The material accumulated would undoubtedly so systematize and extend our knowledge of these important substances, that we should soon be able to determine in advance all the properties of a proposed alloy, and even to ascertain by calculation what alloys could or could not be formed. The extent of research here suggested may be realized when we remember that, out of the sixty-five elements now known, not one has been thoroughly described, or described with even a moderate approximation to thoroughness. These investigations upon the elements would be for chemistry and physics what the preparation of star-maps and planetary tables is for astronomy, or the dissection of the human frame for medicine. They would certainly furnish a foundation for exact physical science such at at present is scarcely even begun.

After the examination of the elements would come the consideration of compounds. These should be taken up, series by series, in some regular order, and at least every typical body carefully described. Thus, step by step, the lines of assault would be drawn around the besieged problems, until at length the citadel would yield, exactness would replace the present chaos, and definite laws would stand where now are speculations. Could any branch of applied science fail to reap a benefit from this result? Would not every industry in any way dependent upon either chemistry or physics be helped? Apart from direct applications of science to the arts, the mere substitution of accuracy for inaccuracy in questions of scientific principle ought greatly to facilitate technological investigations, put new weapons into the hands of the artisan, and so add immensely to the resources of civilized life.

The investigations here indicated are not by any means the only researches proper for an endowed laboratory. They are merely types, to illustrate the general character of work which such an institution should do. It is true that, although individuals cannot deal with these greater problems in their entirety, individuals may, working separately and disconnectedly, contribute much toward their solution. But, unfortunately, researches of this kind are among the most difficult and arduous. They savor much of hard routine and yield no quick return of glory to the investigator, who, already familiar with monotony in his ordinary duties, naturally prefers to undertake labors producing with less effort a more immediate reputation. The discovery of new compounds is less troublesome, and brings speedier celebrity; hence the more solid work of establishing accurate numerical data is very little done. When done, it is done piecemeal. Garden flowers are so much easier to raise than oaks.

Now, assuming that a laboratory for research ought to be established, let us consider some of the leading questions as to its arrangement and organization. First, with regard to the building. This need not be very expensive, since architectural experiments have no necessary

connection with the purposes in view. It should be plain and substantial outwardly, sufficiently spacious within, accessible to much sunlight, and away from the heavier jar of traffic. The suburbs of a great city would be perhaps the most advantageous position for it to occupy. The most serious considerations, however, would concern its interior arrangements. It should, of course, contain a sufficient number of rooms for the accommodation of different branches of research; for example, a photometric room, another for gas analysis, a third for electric measurement, a fourth for calorimetric work, and so on. In the basement, connecting with the solid earth, might be placed a number of heavy stone piers for the support of very delicate instruments. One important item of apparatus would be a steam-engine. This, together with the chemical furnaces and a small machine-shop, might be provided for in a cheap out-building apart from the main structure. Steam, gas, and water, should of course be available in all parts of the laboratory.

But although expense could be avoided in the building, it ought not to be dodged in the purchase of instruments. These would necessarily be of the most costly character. Mere models, such as are commonly used for class instruction, would not suffice. Every instrument of precision used in the laboratory should be a standard of its kind, the best which could be made; otherwise the work of the institution might fall short of the high character intended for it. So also with the chemicals: only the best should be tolerated. As for a library, fitted for scientific reference-work, the cost would depend much upon locality. In a country town, away from other collections of books, the expense would be considerable; but near a city provided with libraries the outlay need not be very great. Still, some money would have to be expended in this very important direction.

Next as regards the working-staff. Since the researches to be undertaken are mainly those which involve the coöperation of specialists, we must start with a sufficiently large and varied body of men. At the head of the institution there ought to be a man of thorough training, proved ability, broad general ideas, and great executive capacity. He should guide and systematize all the work of the laboratory, and to him, as to the director of an observatory, the others should be subordinate. Under him should be at least the following corps of principals: one chemist, one electrician, a specialist in heat, another in optics, a mathematician, and an expert mechanic. Upon the last-named individual would devolve the duty of constructing, altering, or repairing apparatus. To this main staff might be added assistants, as many as the means of the laboratory would allow. Some of these minor positions could perhaps be filled by means of fellowships, analogous to those recently established by the Johns Hopkins University. It might be feasible also to admit private investigators and post-graduate students to the advantages for research afforded

by the laboratory, with the understanding that, in return for favors received, they should contribute a certain amount of labor toward the main purposes of the institution. Such volunteers, if I may call them so, could give, say, one-third of their time to this general work, and have the remaining two-thirds for their own investigations. Thus the laboratory might often aid young men of promise and ability, and derive real benefit from them in return. This power of encouraging and directing the beginner in research would not be least among the merits of the institution. For want of just such encouragement many and many a young enthusiast is driven out of scientific work into some field of labor less congenial and often less important. How much the world has lost in this way, how much science has been retarded, no one can ever estimate.

But how much money is needed for all this? That depends partly upon locality, partly upon other circumstances. In a place where building is cheap, real estate low, and living inexpensive, a moderate endowment would go much farther than in a city like Boston or New York. Under the most favorable conditions perhaps half a million dollars would suffice. Such a sum is by no means extravagant. Single individuals have given us much and sometimes a great deal more toward the establishment of a college, school, art-gallery, observatory, library, or hospital. Why not, then, half a million for a laboratory, three-tenths or less to go for building and equipment, and the remainder for permanently endowing the institution? Even a million would not be too much by any means. There are in our country a good many men able to give as much as this, whose fortunes have been made from applications of science to the arts. Here, then, is a chance for them to reciprocate a little, and at the same time to cover themselves with at least posthumous glory. Or, the expense might be borne by Government. A hundred and fifty thousand dollars down for building and outfit, with twenty-five or thirty thousand dollars annually for sustenance, would do very well. If it is right for Congress to equip transit expeditions in the interest of astronomy, it would certainly be right thus to assist the two sciences to which our greater industries are so deeply indebted. In fact, the United States can better afford to incur this very moderate expense than not to incur it. In the long-run the laboratory would be worth as much to the country as either the Naval Observatory, the Coast Survey, or the geological expeditions—all, by-the-way, excellent enterprises, which have received, if anything, less encouragement than they have deserved. The development of science in a nation means eventually the discovery of new resources and the creation of new wealth. Whoever doubts this statement needs only to look at the past achievements of physical science in order to be fully convinced of its truth. What national investment ever brought in richer returns than that famous grant made by Congress to S. F. B. Morse?

Should the proposed laboratory, if established, be independent, or connected with some other institution? That would depend upon a variety of circumstances. If endowed by the United States Government, it surely ought to be connected with and controlled by the Smithsonian Institution. Even an endowment contributed from private sources might well be placed under that management. For the Smithsonian Institution is really a magnificent example of a great trust splendidly administered. Both financially and as regards the interests of science the managers of this institution have done admirably. Money placed in their hands would certainly be well spent. Every dollar would be so handled as to produce the maximum good effect. A laboratory under this control, whether publicly or privately endowed, would assume a national character, and might serve as a centre of coöperation for investigators in all parts of our country.

Leaving Washington out of account, a laboratory for research might perhaps be best established in connection with some good university—like Harvard, Yale, Columbia, Michigan, or Cornell. It would then be already provided with a library and a building-lot, some apparatus at least would be ready to hand, and a strong social element would aid in the attraction of scientific men. Moreover, with such affiliations, the laboratory would often be able to secure good volunteer work from advanced or post-graduate students; an advantage by no means to be despised.

But it is hardly worth while to multiply suggestions. Enough has been said to show distinctly the main points in favor of a laboratory specially endowed for research, and some of the chief considerations which must arise in its establishment. Such a laboratory as is here indicated, a laboratory in which many specialists could combine forces in the more difficult fundamental investigations of physical science, surely ought not to remain long a mere fabric of the imagination, a misty dream of the future. It should be founded—whether by an individual or by the nation it matters little. Let us hope that, before many years pass by, the dream may become a reality.

THE ORIGIN AND CURIOSITIES OF THE ARABIC NUMERALS.

By D. V. T. QUA.

In an article on the "Origin of the Numerals," published in The Popular Science Monthly for January, 1876, the writer remarks: "Having never met with any explanation of the origin of the numerals, or rather of the figures symbolizing them, perhaps I am right in supposing that nothing satisfactory is known of it."

The history of the Arabic or decimal notation is somewhat as follows: The characters of this notation were introduced into Europe, during the tenth century, by the Crusades. From the Arabic, these characters have been traced to the sacred books of the Brahmans of India. It was long supposed that for our modern arithmetic we were indebted to the Arabians. But this, as we have seen, is not the case. The Hindoos communicated a knowledge of it to the Arabians, and we have been unable to trace it beyond the Hindoos: hence we must concede the honor to them of its invention.

To the Arabians, however, belongs the honor of introducing arithmetic into Europe. It was the Arabians who took the torch from the Orient and passed it along toward the Occident, when "westward the star of empire took its way."

The origin of the characters came, undoubtedly, from the fact that the Orientals first learned to count on their fingers and thumbs, and from this originated the *ten* characters employed, and originally called digits, from the Latin word *digitus*, signifying finger. In keeping accounts among the Orientals, one mark represented one finger, or number, thus: . Two horizontal marks, with a connecting line, stood for two, thus: . Three horizontal marks, with connecting lines, would stand for three, thus: ; and four marks in the form of a square, or a triangle, would stand for four, thus:  . Five marks in this form, , was the original figure five in this notation; six marks, thus, , the original figure six. The figure seven was made by marks representing two squares with one of the lines wanting, thus: . The figure eight was made by placing two squares near each other, thus: ; and nine by adding one more mark to the two squares representing eight, thus: . The *zero*, or cipher, was originally a circle, and seems to have come from counting *around* the fingers and thumbs. Hence, once *around* was denoted by one finger, or character, representing one, thus:  and ; twice around, by  and . From this last ar-

rangement seems to have come the *fundamental law* of the decimal notation in which its superior utility consists, and upon which quite recently has been based the metric system of weights and measures. By placing any of the digits in the place of the zero to make the numbers between ten and twenty, we have the law established. The science of arithmetic, like all other sciences, was very limited and imperfect at the beginning, and the successive steps by which it has reached its present extension and perfection have been taken at long intervals, and among different nations. It has been developed by the necessities of business, by the strong love for mathematical science, and by the call for its higher offices by other sciences, especially that of astronomy. In its progress, we find that the Arabians discovered the method of proof by casting out the 9's, and that the Italians early adopted the practice of separating numbers into periods of six figures, for the purpose of enumerating them. The property of the number 9 affords an ingenious method of proving each of the fundamental operations in arithmetic, and it seems to be an incidental attribute of this number. It arises from the *law of increase* in the decimal notation. It universally belongs to the number that is *one less* than the radix of the system of notation. And in this connection it may not be irrelevant to state some facts or curiosities with regard to this number 9. It cannot be multiplied away, or got rid of in any manner. Whatever we do, it is sure to turn up again, as was the body of Eugene Aram's victim. One remarkable property of this figure (said to have been discovered by W. Green, who died in 1794) is, that all through the multiplication-table the product of 9 comes to 9. Multiply any number by 9, as $9 \times 2 = 18$, add the digits together, $1 + 8 = 9$. So it goes on until we reach $9 \times 11 = 99$. Very well—add the digits $9 + 9 = 18$, and $1 + 8 = 9$. Going on to any extent it is impossible to get rid of the figure 9. Take any number of examples at random, and we have the same result. For instance, $339 \times 9 = 3{,}051$. Add the digits $3 + 0 + 5 + 1 = 9$. Take one more, $5{,}071 \times 9 = 45{,}639$, and the sum of the digits, $4 + 5 + 6 + 3 + 9 = 27$, and $2 + 7 = 9$.

The French mathematicians found out another queer thing about this number, namely: if we take any row of figures, and, reversing their order, make a subtraction, and add the digits, the final sum is sure to be 9. For example, $5{,}071 - 1{,}705 = 3{,}366$; add these digits $3 + 3 + 6 + 6 = 18$, and $1 + 8 = 9$. The same result is obtained if we raise the numbers so changed to their squares or cubes. Starting with 62, and reversing the digits, we have 26, then $62 - 26 = 36$, and $3 + 6 = 9$. The squares of 26 and 62 are respectively 676 and 3,844, and $3{,}844 - 676 = 3{,}168$; add $3 + 1 + 6 + 8 = 18$, and $1 + 8 = 9$. This may be exemplified in another way. Write down any number, as, for example, 7,549,132, subtract the sum of its digits $7 + 5 + 4 + 9 + 1 + 3 + 2 = 31$, and $7{,}549{,}132 - 31 =$

7,549,101. Add these digits, $7 + 5 + 4 + 9 + 1 + 0 + 1 = 27$, and $2 + 7 = 9$.

But we have extended already this article to a greater length than we intended, simply wishing to give the origin and history of the decimal notation as far as it can be traced, and will close by stating that this notation is every way adapted to the practical operations of business, as well as the most abstruse mathematical investigations. In whatever light it is viewed, the decimal notation must be regarded as one of the most striking monuments of human ingenuity, and its beneficial influence on the progress of science and the arts, on commerce and civilization, must win for its unknown author the everlasting admiration and gratitude of mankind.

THE SCIENTIFIC LABORS OF WILLIAM CROOKES.

AMONG the active and successful scientific workers of England, at the present time, the gentleman whose portrait we give this month is one of the foremost. Though only in the meridian of his manhood, he has made two discoveries—those of the metal thallium and of the radiometer—which will immortalize his name; while his minor labors in the field of science, both in the laboratory and in the editorial office, are in an unusual degree important and valuable.

WILLIAM CROOKES was born in London, in 1832. His scientific career commenced in 1848, when he entered the Royal College of Chemistry as a pupil of the distinguished chemist Dr. Hoffmann, now of the University of Berlin. He had gained the Ashburton scholarship at the age of seventeen. After two years of study, Dr. Hoffmann appointed him, first, his junior, and then his senior assistant, which post he held until 1854, when he went to Oxford to superintend the meteorological department of the Radcliffe Observatory. In 1855 he was appointed Teacher of Chemistry at the Science College, Chester. In 1859 he founded the *Chemical News*, and in 1864 he became editor of the *Quarterly Journal of Science*.

Mr. Crookes's researches were begun while at the Royal College of Chemistry, his first paper, "On the Seleno-Cyanides," being published in the *Quarterly Journal of the Chemical Society*, in 1851. Since then he has been almost uninterruptedly engaged in private research on subjects connected with chemistry and physics.

In 1861 Mr. Crookes discovered, by means of spectral observations and chemical reactions, the metal thallium; and in June, 1862, and February, 1873, he laid before the Royal Society an account of

its occurrence, distribution, and the method of extraction from the ore, together with its physical characteristics and chemical properties. He also discussed the position of thallium among elementary bodies, and gave a series of analytical notes on the new metal. In the *Journal of the Chemical Society* for April, 1864, he collated all the information then extant, both from his own researches and from those of others, introducing qualitative and quantitative descriptions of an extended series of the salts of the metal. In June, 1872, he laid before the Royal Society the details and results of experiments which had occupied much of his time during the previous eight years, and which consisted of laborious researches on the atomic weight of thallium.

In 1863 Mr. Crookes was elected a Fellow of the Royal Society. In 1865 he discovered the sodium amalgamation process for separating gold and silver from their ores. (This process was discovered independently, and at about the same time, by Prof. Henry Wurtz, of New York.) In 1866 he was appointed by the English Government to inquire into and report upon the application of disinfectants in arresting the spread of the cattle-plague then prevalent in England. In 1871 he was selected as a member of the English expedition to Oran for observing the total phase of the solar eclipse which occurred in December of that year.

Mr. Crookes commenced his research on "Repulsion resulting from Radiation" in 1872. These experiments were suggested by some observations made when weighing heavy pieces of glass apparatus in a vacuum balance during his researches on the atomic weight of thallium. His first paper on the subject was read before the Royal Society on December 11, 1873, and during the last three years Mr. Crookes has sent six other communications to the society on the same subject. The construction of the radiometer is one result of his investigation. At first it was thought that the movement of the vanes in the exhausted bulb was due to radiation, for no movement took place until the vacuum was so good as to be almost beyond the powers of an ordinary air-pump to produce, and as the vacuum got more and more absolute, so the force increased in power; but Mr. Crookes soon found that at a rarefaction so high that the residual gas was a non-conductor of an induction-current, there was enough matter present to produce motion, and therefore to offer resistance to motion. That this residual gas was not a mere accidental accompaniment of the phenomena was rendered probable both by the experiments of Dr. Schuster and by that of Mr. Crookes, on the movement of the floating glass case of a radiometer when the arms are fixed by a magnet, which was demonstrated to the Royal Society on March 30, 1876. Mr. Crookes has since constructed a special apparatus for measuring the vacuum. A vertical plate, instead of continuously ro-

tating in one direction, as in the ordinary radiometer, is suspended by a glass fibre, which it twists in opposite directions alternately. The movement is started by rotating the whole apparatus through a small angle, and the observation consists in noting the successive amplitudes of vibration when the instrument is left to itself, a mirror and spot of light being employed for this purpose. The results of these experiments leave no reasonable doubt that the repulsion is due to the internal movement of the molecules of the residual gas.

In 1875 Mr. Crookes received the award of a Royal medal from the Royal Society for his various chemical and physical researches; and in 1876 he was elected a Vice-President of the Chemical Society.

Previous to his researches on "Repulsion," Mr. Crookes began to investigate so-called spiritualism. As far as it extended, his inquiry into the subject convinced him that certain phenomena obtained under test conditions in his own house were due neither to tricks, mechanical arrangements, nor to legerdemain. He inclined to the opinion that the "medium" possessed what Mr. Sergeant Cox calls psychic force, but he had arrived at no definite conclusions as to the cause of the phenomena when he decided to discontinue their investigation.

Mr. Crookes is the author of "Select Methods in Chemical Analysis," of "The Manufacture of Beet-Root Sugar in England," and of a "Handbook of Dyeing and Calico Printing." He is also joint author of the English adaptation of Kerl's "Treatise on Metallurgy." He has edited and enlarged the last two editions of Mitchell's "Manual of Practical Assaying," and translated into English and edited Reimann's "Aniline and its Derivatives," Wagner's "Chemical Technology," and Auerbach's "Anthracen and its Derivatives."

It is claimed that Mr. Crookes was the first to apply photography to the investigation of the solar spectrum, but his earlier researches were so numerous that it is impossible to refer to them all. We may, however, mention his papers "On the Opacity of the Yellow-Soda Flame to Light of its own Color," "On the Measurement of the Luminous Intensity of Light," "On a New Binocular Spectrum Microscope," and "On the Optical Phenomena of Opals."

CORRESPONDENCE.

THE NATURE AND CAUSE OF FERMENTATION AND PUTREFACTION.

To the Editor of the Popular Science Monthly.

I HAVE read with no ordinary interest the lecture by Prof. Tyndall, published in your issue of December, upon the subject of "Fermentation and its Bearings upon the Phenomena of Disease;" and I desire, with your permission, to submit some points suggested to my mind upon which, according to my own conception, there remains some doubt, and which I should like to see explained. It is not my intention to dwell upon the general subject of the nature and causes of fermentation, but merely to touch upon it, confining myself rather to the question of the causes of putrefaction.

In fermentation and the production of alcohol, the presence of bacteria seems to be constant. Prof. Tyndall holds that the changes resulting in the formation of beer and the production of alcohol are due to the action of these microscopic germs, which, seizing upon the grain, or fruit, elaborate the spirit. Now, it does not seem to me perfectly clear that the changes which take place in the fruit may not be purely chemical, and that a portion of the component elements of the fruit, not requisite to form the chemical combination of alcohol, becomes a suitable soil in which the air-germs can take root and grow. It is a question of cause and effect.

Again, a certain amount of moisture is necessary to the production of mould. It may be asked: Is it quite certain that the moisture is not the agent of a chemical decomposition, and that the growth of mould is due to the deposit of seed in soil furnished by this decomposition? May it not be that a dry and cold atmosphere prevents or retards chemical decomposition in devitalized organic matter, while heat and moisture cause or facilitate it? Why should we disregard the chemical forces in the decomposition of organic matter deprived of vitality? Or, does Prof. Tyndall wish us to regard all organic matter as possessed of vitality until it is decomposed? Indeed, he says: "Cherries, apples, peaches, etc., are composed of cells, each of which is a living unit;" and "the living cells of fruit can absorb oxygen and breathe out carbonic acid, exactly like the living cells of the leaven of beer." We know that the seed of fruit possesses vitality; but is it proof of vitality in the cells, that certain changes take place between the constituents of the cells and the external air, and that other changes take place when the fruit is excluded from the air? Granting it is, then shall we say that all vegetable products, although long since uprooted but undecomposed, are possessed of life? Are the cells which compose the well-worn oak-beams of the few remaining wooden walls of Old England still endowed with vitality, and constantly engaged in a struggle for life with the low forms of animated Nature? Then, if this be conceded, might we not assume that fructification of germs is likewise essential to the decomposition of minerals? If the decay of an old boot is dependent upon the growth of mould, may we not suppose that the rusting of an old axe is due to similar influences; and that the erosion of rock, which in time forms abundant soil for vegetation, is the work of microscopic germs, although commonly supposed to be due to physical forces?

Prof. Tyndall says that "some of the numberless air-germs produce acidity, some putrefaction." But when acidity takes place rapidly, as in a frozen apple just thawed, and with an unbroken skin, are we still to regard it as the result of bacteria? With regard to putrefaction, Prof. Tyndall cites a number of experiments with beef-tea. Now, to make these perfectly satisfactory, it seems to me that the fluid ought to be exposed to not a limited quantity of pure air, but a free change of air from which all motes had been removed.

I now come to the subject of putrefaction in connection with the living body, and the antiseptic treatment of wounds as taught by Prof. Lister, of Edinburgh. Prof. Tyndall says that he has obtained "a specific against putrefaction and all its deadly consequences." This statement might lead the public to believe that the teachings of Prof. Lister were generally accepted by the medical profession. Such, however, is by no means the case, notwithstanding his practice has been thoroughly tried in most if not all the principal hospitals of Europe and America. While a certain number have adopted his method, the majority have rejected it, with the conviction that other treatment less troublesome is quite as, if not more, successful. That Prof. Lister's theories and practice are not believed in by the representative surgeons of the United States, was clearly demonstrated at the late International Medical Congress, at Philadelphia. Prof. Lister was

chairman of the surgical section, and he was courteously allowed all the time and opportunity he desired, which was a good deal, to fully explain his views. But, after all, the section refused to indorse his mode of treating wounds. The presence of germs in the air was not denied; the views of Pasteur were not disputed; but the question was, Have these theories, facts if you please, any necessary connection with putrefaction? The question was and is: Is it true, or not true, that putrefaction cannot take place without the presence of air-gems? Is it true that animal organic matter, when deprived of vitality, will remain undecomposed for an unlimited time unless bacteria seize upon it; or will it not, by a purely chemical process, decompose? Decomposing organic matter, we know by daily observation, is the abode of low, degraded animal life, and the soil in which low forms of vegetable life take root and grow; but are we to regard this as the cause or the result of putrefaction? If it be admitted that putrefaction may, under any circumstances, in the absolute absence of bacteria, take place as a chemical process, is it not begging the question to assert that their presence is ever necessary? Every surgeon knows that putrefaction does often take place in the body beneath an impervious skin. This fact was accounted for by Prof. John T. Hodgen, of the St. Louis Medical College, who was the surgical reporter at the recent congress, upon the subject of antiseptic surgery, on the supposition that the bacteria reached the place of putrefaction through the lungs, or stomach, and the blood. He also declared that bacteria had been found in wounds beneath Prof. Lister's most elaborate and carefully-prepared dressings; and that they must have found their way there through the blood. But Prof. Lister took occasion to repudiate this doctrine. He did not believe the germs arrived at the wound by way of the blood-vessels; and we can understand why he should reject this theory. The writer of this communication then pointed out the uselessness of Prof. Lister's antiseptic dressing externally, if bacteria could enter by another way. Prof. Lister not only denied this theory, but admitted that putrefaction did sometimes take place independently of bacteria as a chemical process. The writer then submitted, and it is submitted now, that if putrefaction ever takes place without the influence of bacteria, it is impossible to prove that it, in any case, depends upon their presence.

It is no uncommon experience of surgeons to see wounds heal rapidly without putrefaction, although no steps are taken to place a barrier to the entrance of air-germs, or to destroy those which may have lodged in the part. Undoubtedly the air is, sometimes, especially in badly-ventilated hospitals, loaded with germs of a specific and poisonous nature, which will contaminate any wound, as the poison of erysipelas, but that common unadulterated air is inhabited by organisms whose existence and operation are essential for putrefaction, remains unproved. The value of carbolic acid and similar agents is generally acknowledged by the medical profession. They are in constant use, but not with the view of destroying germs. They are found to possess the property of arresting or preventing putrefactive chemical decomposition—just as common salt has in preserving meat—and hence their usefulness in the treatment of wounds.

When Prof. Tyndall "passes the bounds of surgery and enters the domain of epidemic disease," and points out the analogy between *contagium* and fermentation, he gives utterance to views long held by the medical profession. That small-pox, scarlet fever, etc., are developed in the system by "indefinite self-multiplication of germs (zymosis) introduced from without," is a commonly-accepted doctrine.

In support of the statement that Prof. Lister's antiseptic method is not regarded as essential to the successful treatment of wounds, one fact may be given, although more might be furnished. Prof. Spencer, who occupies the chair of surgery in the Edinburgh University, and who is therefore a colleague of Prof. Lister's, and likewise the author of a highly-esteemed work on surgery, continues to treat wounds without reference to Lister's theories, with results quite as satisfactory as any claimed by Prof. Lister. WILLIAM CANNIFF, M. D.

TORONTO, *December* 12, 1876.

INSECTS AND FLOWERS IN COLORADO.

To the Editor of the Popular Science Monthly.

ALLOW me to express my thanks to Prof. Gray, and Mr. Putnam, in so kindly furnishing the facts I asked for in regard to the insects of Colorado. Since my inquiry was written, Prof. Gray has defined his position in the January number of the *American Agriculturist*. He does not contend for the general necessity of cross-fertilization as Lubbock, Wallace, and others have done, but simply that an occasional cross is beneficial. When flowers are not visited by insects, they generally self-fertilize. "'Cross-fertilize if you can, self-fertilize if you must,' is Nature's golden rule for flowers." Of course this narrows the question to the *benefits of an occasional cross*, and renders much that I have written no longer of account. Of this character is this question of the quantity of insects in Colorado.

If plants can "generally" fertilize themselves without insect aid, simply preferring cross-fertilization through insect agency when they can get it, the abundance or partial absence of insects there is of little consequence in the argument.

The question being purely entomological, and no longer of importance to the botanist, I should feel sorry for having put Mr. Putnam to the trouble of writing his letter, only that I know facts are always welcome to the lover of science, though they may have no immediate bearing on questions under discussion. THOMAS MEEHAN.

GERMANTOWN, PA., *February* 22, 1877.

THE MATHEMATICAL CONTROVERSY.

To the Editor of the Popular Science Monthly.

SIR: You will doubtless be gratified to find that the premise upon which you have rested a charge of disingenuousness against a gentleman no longer living is mistaken. The case is this: You find that the negatively-quantitative geometry of Spencer's first edition of his "Classification of the Sciences" must have been that branch of mathematics which has grown up under the name of "Descriptive Geometry;" and you find the late Mr. Chauncey Wright disingenuous in representing that Spencer had reference to those technical methods of geometrical construction to which engineers apply the name. But Wright, like you, understood Spencer to refer to Monge's descriptive geometry; and it was just that which he characterized as a mathematical art having no place among the abstract sciences.

Permit me to add that I used to talk with Wright, daily, while he was writing the article in which this matter is discussed; and I declare that nothing could less describe his method than to say that he "was hunting through Spencer's various books in search of flaws." On the contrary, no critic ever studied his author more conscientiously; and very few have succeeded as well as he did in comprehending thought remote from the channel of their own. The present case illustrates this, for Wright seemed to detect that Spencer had two very different things confounded together in his mind, viz., descriptive geometry and positional geometry. The second edition of Spencer's book makes it pretty clear that this is so; for some of his warm disciples maintain that he still means the former, while to the mathematician his present words describe with tolerable accuracy the latter.

No doubt, Wright greatly under-estimated the importance of Herbert Spencer's philosophy. This was natural, because he found in Spencer's fundamental doctrine of the universality of evolution a proposition radically opposed to his own theory that there is only an ebb and flow, in this respect, and no unending progress. But such sharp antagonism only serves to make his criticisms all the more instructive. Whatever there may be of extravagance in the claims which are made for Spencer will be overthrown in the course of the discussion which is sure to go on, and which he himself would be among the very last of men to deprecate. It would be strange, indeed, if it were to turn out that an encyclopedic system of philosophy had been produced, so perfect in its details as to satisfy specialists. But disputation clears the philosophic air, and can only serve to bring into the light and to sharpen the outline of all that is to abide in Spencer's system. In this point of view, I cannot agree with you that Mr. Spencer's distinguished candor has done him any harm, or has postponed the knowledge of the truth for which he is striving.

Mr. Wright occupied a position opposed to that of most modern mathematicians, in maintaining that positional geometry is not quantitative. This, however, is not a question of mathematics, but of logic: and it goes very deep into the theory of logic, too. But, while it does not concern the "mathematical expert," as such, one does not perceive that Mr. Spencer has proved himself so supremely the master of the philosophy of mathematics that we need be greatly anxious lest Mr. Cayley should have ventured to express himself on the subject, without proper study of what Spencer has said.

You well say that we here "encounter a difficulty which always arises when knowledge outgrows old definitions." Prof. Peirce, in his "Linear Associative Algebra," offers a definition of mathematics, the acceptance of which would not necessarily involve any decision of the question whether that geometry which is not metrical is quantitative or not. Although linear associative algebra is certainly not popular science, perhaps you will find his remarks of sufficient general interest for insertion. He says:

"Mathematics is the science which draws necessary conclusions.

"This definition of mathematics is wider than that which is ordinarily given, and by which its range is limited to quantitative research. The ordinary definition, like those of other sciences, is objective; whereas this is subjective. Recent investigations, of which quaternions is the most noteworthy instance, make it manifest that the old definition is too restricted. The sphere of mathematics is here extended, in accordance with the derivation of its name, to all demonstrative research; so as to include all knowledge strictly capable of dogmatic teaching. Mathematics is not the discoverer of laws, for it is not induction; neither is it the framer of theories, for it is not hy-

pothesis; but it is the judge over both, and it is the arbiter to which either must refer its claims; and neither law can rule, nor theory explain, without the sanction of mathematics. It deduces from a law all its consequences, and develops them into the suitable form for comparison with observation; and thereby measures the strength of the argument from observation in favor of a proposed law, or of a proposed form of application of a law.

"Mathematics, under this definition, belongs to every inquiry, moral as well as physical. Even the rules of logic, by which it is rigidly bound, could not be deduced without its aid. The laws of argument admit of simple statement; but they must be curiously transposed before they can be applied to the living speech and verified by observation. In its pure and simple form, the syllogism cannot be directly compared with all experience, or it would not have required an Aristotle to discover it. It must be transmuted into all the possible shapes in which reasoning loves to clothe itself. The transmutation is the mathematical process in the establishment of the law. Of some sciences it is so large a portion that they have been quite abandoned to the mathematician, perhaps not altogether to the advantage of philosophy. Such is the case with geometry and analytic mechanics. But in many other sciences, as in all those of mental philosophy and most of the branches of natural history, the deductions are so immediate, and of such simple construction, that it is of no practical value to separate the mathematical portion and subject it to isolated discussion.

"The branches of mathematics are as various as the sciences to which they belong, and each subject of physical inquiry has its appropriate mathematics. In every form of material manifestation there is a corresponding form of human thought, so that the human mind is as wide in its range of thought as the physical universe in which it thinks. The two are wonderfully matched. But where there is a great diversity of physical appearance, there is often a close resemblance in the processes of deduction. It is important, therefore, to separate the intellectual work from the external form. Symbols must be adopted which may serve for the embodiment of forms of argument, without being trammeled by the conditions of external representation or special interpretation. The words of common language are usually unfit for this purpose, so that other symbols must be adopted, and mathematics treated by such symbols is called *algebra*. Algebra is, then, formal mathematics." I am, etc., C. S. P.

We cheerfully give place to the foregoing, prompted as it is by the generous desire of the writer to speak for one who can no longer speak for himself. Yet it hardly appears how our correspondent has much improved his friend's case. He objects, on the strength of intimate acquaintance with Mr. Wright and the spirit of his work, to our remark that he "was hunting through Spencer's various books in search of flaws." We certainly are not entitled to speak of Mr. Wright's motives, any further than they can be fairly gathered from his writings. No fair-minded person, acquainted with Herbert Spencer's labors, can deny that Mr. Wright's criticism upon him, in the *North American Review* of 1865, was a very prejudiced piece of work. C. S. P. admits that he greatly under-estimated the importance of Spencer's philosophy, which he accounts for by the natural bias of one who entertains rival views in the same field. Yet the article was far less a judgment of the philosophy, of which but a single volume had then appeared, than an estimate, gathered from an examination of Spencer's various productions, of his competency to produce a philosophy. He undertook to measure the man, and, as we now understand, with a predisposition to underrate him. He, therefore, could not have approached his works in an impartial or judicial temper, but rather in a state of feeling which interested him in their defects. At any rate, if he was not in quest of flaws, it is difficult to see how it was that he found nothing else. Six years before Mr. Wright wrote, and before Mr. Spencer had published a word of his philosophy, several of the ablest men in England joined in an appeal to the Government to secure for him a position of trust, on the ground that he was eminently the man to do a great and special work for the advancement and organization of knowledge that should be a national honor; and now, a dozen years after Mr. Wright wrote, the sixth volume of his philosophical system is awaited with eagerness by the leading minds of the foremost countries in the world. That is to say, he is doing the work that English philosophers predicted long ago (on the basis of what he had already published) that he would do. His works must, therefore, have had some excellences, some elements of strength, which it was the duty of candid criticism to recognize. But Mr. Wright seems to have

seen in them little except evidences of "ignorance," "incompetency," "confusion," "inconsistency," "perverted terminology," "fanciful discriminations," and, massing together these faults, he winds up his article with the inference of Spencer's "incompetency for the further development of his encyclopedic abstractions." This looks very much to us like "picking flaws," under the inspiration of a not very creditable purpose.

As to the special case there can be no doubt that Mr. Wright made a charge of ignorance against Mr. Spencer, founded on misrepresentation. He says that in his mathematical classification Spencer "has given a prominence to descriptive geometry which might be regarded as arising from the partiality of the civil engineer for a branch of his own art, were it not that he says, 'I was ignorant of the existence of this, as a separate division of mathematics, until it was described to me by Mr. Hirst.'" The insinuation is that Spencer, though educated as a civil engineer, was unacquainted with the branch of mathematical art that is especially familiar to engineers. That this imputation was groundless may be proved by referring to the *Civil Engineer and Architects' Journal* for 1839–'40, where will be found conclusive evidence of Mr. Spencer's early and thorough familiarity with the subject. Among other original papers in the field of descriptive geometry there published will be found a beautiful original theorem which dates back to the time when Spencer was but seventeen. He was not, then, so ignorant as Mr. Wright intimated, and certainly not so grossly ignorant as to confound a practical art with an abstract science, as erroneously represented by his critic. Although the arts grow into the sciences, so that both often pass under the same name, it requires no great discrimination to separate them; and if a question could arise as to which is meant, the character of the discussion would sufficiently determine it. Mr. Wright was no more justified in assuming that, by "Descriptive Geometry," as he was dealing with it, Mr. Spencer meant "certain methods of geometric construction, useful in engineering," than that by "geometry" he meant the art of earth-measuring instead of the science, or by "chemistry" the art of manufacturing paints and dyes, instead of its scientific principles. By the term "descriptive geometry," employed, as it was, in its scientific significance, Mr. Spencer did not mean Monge's "Géométrie Descriptive" of a hundred years ago, in which theorems and their applications to drawing were mingled together, but he meant the branch of mathematical science which has since grown up under this title, while omitting all mention of the practice that gave it the name of Descriptive Geometry, and for which the title Geometry of Position is now substituted. As Mr. Wright suggests the alternative that Mr. Spencer may have meant something else than what he imputed to him as the basis of a charge of ignorance, it is fair to infer that he did not know what he meant; and if he had not been animated by a predisposition to make out a bad case, he would have abstained from taking up the point, or would have dealt with it in a different spirit. We desire to do no injustice to the memory of Mr. Wright, but, as his works are now brought forward in a collective and permanent form, they are the proper objects of criticism, and we have commented upon one part of them, solely in what we consider the interest of truth.

EDITOR'S TABLE.

INTERNATIONAL COPYRIGHT.

DR. C. E. APPLETON, of London, has an article in the February *Fortnightly* on "American Efforts after International Copyright," which gives a generally correct account of what has been done here within the last few years to promote that object, but which places us in a false position, which we do not care to occupy. The interest of the topic is such that a few remarks of correction and reminiscence are here proper.

There was a revival of interest in the subject in 1871, which began in an English discussion, when Mr. W. H.

Appleton, of New York, wrote to the London *Times* that he did not think the American people were opposed to a copyright which had no other object than to secure the recognition of the rights of property of foreign authors in American editions of their works. He said that such a copyright had never been asked for by England, but only an arrangement to protect English printed books, by which the foreign manufacturer could get protection on his stock of paper, printing, and binding, in the American market under cover of his authors' copyright. The publisher's share in the production of a book—in materials and labor, which have a cash value in the market—may be assumed as at least ten times greater than the share contributed by the author, and which is represented by his customary ten per cent. royalty. Such international copyright laws as have been demanded are, therefore, ten times more for the protection of foreign book-manufacturers than for foreign authors. "Disentangle your author from the publisher," said Mr. Appleton, "and let him present his own claims, and my opinion is the American people will not deny them." The fairness of this position was acknowledged by the English press, but the English publishers were silent. The English authors, on the other hand, or a large proportion of the most influential of them, conceded the justice of the case, and drew up a memorial asking for negotiations on the new basis.

This stirring up of the subject led to some efforts on this side, to carry out the fundamental idea which Mr. Appleton had presented, and which had been previously urged in this country. There was at first but very little objection to the plan, and there was a general expression of favorable feeling toward an adjustment on the basis proposed. But opposition was quickly and vigorously developed, because the parties interested in the frustration of the measure were few and powerful, deeply concerned, and able to concentrate a prompt and efficient opposition. This fact we think was not sufficiently calculated upon, and the practical issue was brought before Congress prematurely, in the shape of a bill embodying a copyright in behalf of foreign authors. More time should have been allowed, and systematic measures adopted to sift the question thoroughly before the American people. We had a society organized for the promotion of international copyright, but it was committed to the old plan, and threw the weight of its influence against the new measure.

In this unfavorable state of things, when the opportunity had been adroitly seized by the tacticians opposed to copyright to confuse and befog the public mind by proposing all sorts of projects, a congressional committee was appointed, who called a meeting on February 12, 1872, for the hearing of all parties interested. We attended it, and it was certainly a very funny affair. We had not been accustomed to the atmosphere of Washington, and were, therefore, but poorly prepared for the sarcastic intimations of parties who lived there, as to the greenness of the gentlemen who came to the national Capitol expecting to interest Congress on such a question as this in a presidential year. The subject was discussed by various speakers, and in his account of it Dr. Appleton says, "Prof. Youmans followed, urging the claims of British authors upon the singular ground that they were very badly paid in their own country, and desired American sympathy." This is a total mistake; we argued the question on no such grounds, and offered no hint of any such reason why international copyright should be secured.

We demanded it of Congress solely as a measure of justice, and there was need enough that this view of the case should be urged; for the discussion before the committee was in the last de-

gree wild and discordant. All sorts of projects and crotchets were thrust forward on all sorts of pretexts. A lawyer was there to represent the Harpers, who opposed international copyright, but for reasons which he admitted would carry with them the destruction of all copyright. He presented a letter from the publishers for whom he was arguing, in which they said the claims of authors were not to be considered, but only the interests of the people at large. But why the people, having taken the communistic hint, and plundered the authors for their own benefit, might not go through the Franklin Square establishment and help themselves, in the interest of cheap knowledge, was not stated. The idea that there was any principle of right in the matter, which it was the duty of Congress to recognize, seemed to be quite lost sight of. The game of defeating the measure for an author's copyright (which it was feared at first might succeed) consisted in bringing up a great number of rival projects to bewilder the question, and the game succeeded. The committee reported against any congressional action, on the ground that it was not called for by equity, while those who professed to be in favor of the measure could come to no agreement in regard to a plan.

It may be added that, while we made no statement before the committee as to English authors being poorly paid, there was a comparison of the American method of payment by a percentage on the sales, with the English system of giving the author half-profits. The American method was commended and the English declared to be one from which their authors suffered; for, while by the percentage plan the author always gets something if there are any sales, on the English plan he gets nothing unless there are profits. And as, first, on the great mass of books there are no profits, and as, second, the making up of the "cost" is entirely in the hands of the publisher, the authors are liable to be victimized by the policy. In proof of this, and in explanation of how badly the half-profit system works for authors, we read from a pamphlet by James Spedding, an English author, in which the whole thing is exposed. He wrote it as two magazine articles, and could not get them published, because the editors said they should thereby make enemies of the publishers. So Spedding published the papers himself. We, however, made no absurd attempt to get up sympathy for English authors because they may be badly used by some of their publishers at home.

THE ORDER OF NATURE.

Some of the questions propounded to us through the columns of the *Tribune* by the Rev. Dr. Deems we answered in the preceding number of the Monthly, and postponed, for lack of space, the consideration of the following:

"The professor says that 'Prof. Huxley's antagonists hold that the inflexible order of Nature may be asserted, perhaps, in astronomy, but they deny it in biology.' Will he be good enough to refer me to one of the professor's antagonists who 'holds' that opinion?"

We here made an affirmation concerning a class, and Dr. Deems challenges us to produce a single instance in which it is true, which may be taken as an emphatic way of expressing his disbelief in what we said. Recurrence to the matter satisfies us that, besides being true, the proposition is more broadly true than we affirmed it to be. That the order of Nature is a principle accepted only in part, is a view held, not only by those who are ranked as antagonists of Huxley, but by the great mass of people, including even the largest proportion of scientific men. We have received, from Mr. W. H. Walworth, of Monticello, Iowa, a letter of inquiry that so clearly brings out the

attitude of mind to which we referred, that an extract from it will be here useful. Mr. Walworth remarks:

"You say (in your critique of Dr. William M. Taylor): 'And here is the vital point between Prof. Huxley and his antagonists. It is a question of the validity of the conception of the order and uniformity of Nature. Prof. Huxley holds to it as a first principle, a truth demonstrated by all science, and just as fixed in biology as in astronomy. His antagonists hold that the inflexible order of Nature may be assorted, perhaps, in astronomy, but they deny it in biology. They here invoke supernatural intervention. Obviously there are but two hypotheses upon the subject: that of genetic derivation of existing species, through the operation of natural law, and that of creation by miraculous interference with the course of Nature. If we assume the orderly course of Nature, development is inevitable; it is evolution or nothing.'

"Very well; it is evolution or nothing. Now, if evolution is true in biology, as Prof. Huxley maintains, my inquiry relates to the matter of the beginning of that evolution, and the beginning of life. Scientists do speak of the beginning of life. Is there a new force or a new principle introduced at this point that scientists have in mind when they say 'the beginning of life?'

"If so, does that new force or principle come through a miraculous interference with the course of Nature? If not, is life in its beginning other or more than a fact, and its appearance a phenomenon both to be accounted for by evolution in conjunction with matter and its inherent forces and principles?

"Given: First, the planet without life (so called); afterward, the planet with life.

"Then, if evolution is the law of 'dead matter,' and at the same time the law of 'living matter,' is there any chasm between that evolution does not bridge over?

"In other words, if evolution is the law, is there any escape from the conclusion that the beginning of life (so called) is a product of it, unless we accept the hypothesis of miraculous intervention? And why is any scientist permitted to entertain that hypothesis (miraculous intervention), at this particular point in the course of Nature (the point of the beginning of life), while he claims the right to reject it at all the other points along the line?"

This last question implies, what is perfectly well known, that many scientific men, naturalists, and even advanced biologists like Mr. Darwin, do invoke miraculous agency to explain the origin of life upon earth; that is, after admitting generally the great principle of natural causation, at a certain point they throw it up as insufficient, and appeal to supernatural causation.

It is surely unnecessary to waste words here in showing that the conception of the order of Nature has had an historic growth; that in the early times all the operations of the world were explained on the hypothesis of supernatural agents which science has so far dispelled as imaginary that the great phenomena of the heavens, the changes of the crust of the earth, and even atmospheric disturbances, are now referred for explanation to the operation of inflexible and universal physical laws. Where explanation breaks down and difficulties remain, in these branches of inquiry, the course pursued is to attribute the unexplained effects to lack of knowledge, and to wait for further light from the sources that have already afforded it. Nor can it be necessary to multiply words in showing that it is not so in biology, the science which deals with the phenomena of life. When a formidable difficulty occurs here, such as explaining the origin of species or the first advent of living things upon the earth, there is no waiting, but the knot is cut at once by appealing to miraculous intervention—to causes that are above Nature and out of Nature, and which cannot be investigated. There are, indeed, but few, even in the circles of science, who avowedly maintain the inviolable supremacy of natural causes, here as elsewhere, in Nature. They assume it generally, but affirm its inadequacy to explain all efforts. How many are there who recognize man, in his origin, to be as strictly and essentially a part and result of the order of Nature as any other creature? Like

Wallace and Dana, they go nine-tenths of the way, and then fly the track. Nature may do a large amount of the lower work; but for the origination of the higher part of man we must appeal to agencies higher than Nature.

Our correspondent does not see the reason of this. He asks why scientists are to be permitted to invoke miraculous agency at the point of the introduction of life, while they reject it at all others along the line of its development. They can only do this at the expense of logical consistency, and, so far as they do it, are unscientific. If a scientist does not know how life began, he should say so; and if he cannot find out himself, he has only to leave the inquiry to others. He is bound to explain it rationally, as he explains other effects in Nature, or to suspend his judgment. It is futile for him to resort to any short-and-easy methods of solving the problem, for it still remains to be worked by the scientific method. The whole history of our knowledge of Nature reveals an immutable order, an invariable and indissoluble chain of causation; and this principle a scientific man is never at liberty to discard because a serious difficulty is encountered; and, as a scientific man, he is never at liberty to discard it at all. Men talk lightly of breaks and supernatural intrusions in the course of Nature, which was well enough ages ago, but is now forbidden by the very conception of what Nature is. For thousands of years nothing was known of natural laws; now they form the basal idea of its constitution. The innermost texture, the essence and spirit, and the very definition of Nature, are unbroken, continuous order. It is by this alone that we know it. It is not enough to say that law is universal. It pervades all Nature, and constitutes the very idea of it. Our intelligence is bound up with it, is a part of it, and we neither know nor can know of any exception or limit to the principle. Men undertake to say where the natural order stops, and the supernatural is reached, but they juggle with words; for, the moment the so-called supernatural is brought within the cognizance of reason, it ceases to be supernatural. The alternative and antithesis of natural order is not the supernatural, but disorder. As the Rev. Baden Powell well remarks, "If Nature could really terminate anywhere, there we should find not the supernatural, but a chaos, a blank—total darkness—anarchy—atheism."

As to the chasm of which Mr. Walworth speaks between dead and living matter, it is, of course, nothing more than a chasm in our knowledge, and none the less a chasm when bridged over by the hypothesis of miraculous interference. The lowest form of life, the material basis from which all living things are spun, is protoplasm; but if Nature can produce a Newton or a Shakespeare in a few years from a formless protoplasmic germ, and by the course of natural causation, why should we say that it is past her power to produce the raw material itself, and fly to the supernatural to account for its earliest appearance? Science cannot take the theological explanation here, any more than elsewhere in Nature, for, if these explanations had been accepted as satisfactory, there never would have been any science. The scientific problem of the origin of life is a recent one. It has not been solved, but what has been already done, so far from disheartening inquirers, only stimulates them to greater effort. Chemistry already begins to build up organic substances artificially in the laboratory, although such an idea was long scouted as hopelessly impossible. A few generations more of work may put a very different aspect upon this profound inquiry; but, even if it takes centuries, the question must be held as belonging solely to the province of reason, and to be solved in accordance with the natural laws of cause and effect.

TOM EDWARD'S BIOGRAPHY.

Our notice of the career of Thomas Edward, printed last month, has elicited much interesting and sympathetic comment from the press, accompanied in repeated instances with something like skepticism as to its verity, or the possibility that a man of such genius could have been so long neglected in a community claiming the slightest degree of civilized intelligence. The story will appear more incredible in this country, where we can hardly appreciate the intensity of the class-feeling that pervades British society. The open secret of the case is, that Edward was a laborer, and not a gentleman, and, belonging to the servile class, he was not recognized or aided by the people around him. Scientific men corresponded with him, but they were at a distance, and probably neither knew nor inquired anything about his personal circumstances. And so he was left to fight his course alone, which he did manfully and bravely, contented if he could only work. The world never heard of Banff before, and it will be now known more for its meanness toward a poor shoemaker than for any other cause. But what shall we say of the meanness of the reviewer who thinks that the world should not have been apprised of the career of this remarkable naturalist until after his death? The Banff people, it is to be presumed, will not offer much excuse for their neglect, but a reviewer can express regret that justice has been done him by a distinguished biographer, as if he grudged the man the satisfaction of being justly recognized in his declining years. It was not enough that he should never have been the recipient of any aid to facilitate his scientific studies, but he must be refused also that reward which is the spur of ambition to the highest natures, the sympathy and approbation of their fellow-men! And if there be a lower depth of meanness yet, a reviewer can find it. Although Edward had been battered through a career that would have killed most men, enduring privation and exposure until health gave way with the approach of old age, yet the critic of the London *Academy* fears that the effect of publishing this premature biography will be, that no more work can be got out of the old man. This is what he says:

> "Interesting and valuable though this memoir of a self-helpful and a self-denying life undoubtedly is, we are not sure that Mr. Smiles would not have acted a wiser part in deferring its publication. For it is rather bold to assert of one who is but threescore and two, and has shown but few signs of mental decline, that '*hic jacet* is all that remains to be added.' Rather we would hope that the downward course of Edward's life, smoothed by the queen's recognition of his services, may be a long and useful one, and that, having survived the danger of unmerited neglect, he may be spared the harder trial of intrusive patronage, to which this premature biography is likely enough to expose him. It is a perilous precedent for a successful author to have set, and we could have wished, for the sake of others, that Mr. Smiles had denied himself the pleasure of forestalling the verdict of posterity, and had culled his last example of self-help from a career already concluded."

LITERARY NOTICES.

Notes on Life-Insurance. Third edition. Revised, enlarged, and rearranged. By Gustavus W. Smith. New York: D. Van Nostrand. Pp. 204. Price, $2.

This book is an attempt to unfold the "mystery and art" of life-insurance, to the general reader; to put before him in simple form, rid, as far as may be, of technicalities, a statement of the data upon which life-insurance problems are based, and the methods by which they are solved. For fifty years and more the business has been prominently before the public. It has been urged and expounded with a zeal and persistency that have become proverbial, and the inference is natural that there ought, by this time, to be among the people at

large a respectable amount of acquired information about it. Such, however, is not the case. The savings of the frugal have been embarked to the extent of $2,000,000,000 in schemes which claim to be designed for their mutual protection, not upon informed and deliberate judgment, but in great part as the simple result of yielding to the blandishments of the canvasser, combined with a sublime faith in the efficacy of statistical tables and mathematical formulæ which were not understood. Recognizing the extent of this ignorance, and the discomfort and distrust to which it is likely to give rise, the author has tried to make the road to knowledge in this direction easier. He has put into reasonable limits, and into logical and accessible shape, the more essential information pertaining to the theory of life-insurance, which heretofore was only to be gleaned from rare and expensive books, which were quite out of the reach of the non-professional reader. That this was no easy task is a fact which should be taken into account when measuring the degree of his success.

The book is divided into two parts. Part I. is theoretical. The tables of mortality are given, and we are shown how from these are obtained the expectation of life, and—assuming a given rate of interest—the net premium and the reserve—or, as the author prefers to call it, the trust-fund deposit. The theory of annuities is discussed in a series of problems; and the mechanism of the commutation-tables—those working-tools of the actuary—is explained.

Part II. is devoted to the discussion of such practical considerations as: the general management of companies; stock and mutual rates; the various plans of insurance; gross and net valuations, which involve the relation of the companies to the State; surrender values; annual statements, etc. The views under these heads are sound and well put, and, if they were widely circulated and read, would contribute to the welfare of both managers and the insured, and help to put their relations upon a surer footing. Algebraical discussions and formulæ and tables are relegated to an appendix, where they can be mastered or omitted, as the reader may choose.

We warmly second the author's hope that this little volume will be widely distributed and carefully studied, but must confess we are not very sanguine about the latter. It is true, as he says, that it contains no science that is very abstruse; there is nothing which a man with a little arithmetic and less algebra may not master, but it does imply that he should put himself to the strain of a little application and study, and this is just what the majority of men are unwilling to undertake. To average an interest account is a very simple matter, but most men who have never learned or have forgotten how to do it will, when one is rendered to them, take the chances on its correctness rather than take the trouble to verify it, and insure themselves against loss.

The issue of this third edition is timely. The management of insurance companies is a matter over which the public mind is just now very properly exercised. We know of no other attempt to give the information required for its intelligent consideration, and, so far as Mr. Smith's book succeeds in throwing light upon the subject, it will be doing a good work.

The Functions of the Brain. By David Ferrier, M. D., F. R. S. With numerous Illustrations. New York: G. P. Putnam's Sons. Pp. 323. Price, $3.50.

This work embodies the last considerable effort, made by experimental physiology, to unravel and explain the mode of action of that most complex and obscure of all mechanisms—the brain of animals and of man. The author wisely says: "We are still only on the threshold of the inquiry, and it may be questioned whether the time has even yet arrived for an attempt to explain the mechanism of the brain and its functions." Much, however, has undoubtedly been accomplished toward the attainment of this end, though the steps forward are slow, uncertain, and difficult. What can be positively gained by any special research seems so small in comparison with the complete problem to be solved as to be hardly worth the immense labor involved; yet there is a fascination in the inquiry, and a grandeur in the result aimed at which awakens the enthusiasm of inves-

tigators, and assures the continuance of indefatigable research. Dr. Ferrier's investigations led him to certain important conclusions regarding the localization of functions in the brain, which have been approved by some physiologists, and criticised by others, although all agree as to the value of his skillful and well-directed experiments. The chief object of this volume is to present the author's views of the bearing of his experiments, although it contains a concise and well-digested account of the functions of the cerebro-spinal system in general, with the view more especially of pointing out the mutual relations between the higher and the lower nerve-centres. Dr. Ferrier's work was elaborately reviewed and in some respects adversely criticised by Mr. George Henry Lewes in two numbers of *Nature*. We have no space to state the points in issue, but will give his estimate of the work as presented in the closing passage:

> "My space is exhausted, and I have not been able to do more than criticise the main topic of Dr. Ferrier's book—and this not with the fullness which its importance demands. But if I have shown grounds for regarding the hypothesis of voluntary centres in the cortex as at any rate far from *proved*, and in doing so have had to adopt an antagonistic attitude throughout my review, I should not be just to him, nor to my own feelings of gratitude, if I did not, in concluding, express a high sense of the value of his work, full as it is of suggestions, and rich in facts, which no counter-facts can set aside. It will long remain a storehouse to which all students must go for material. It may be the starting-point of a new anatomy of the brain."

The Carlyle Anthology. Selected and arranged with the Author's Sanction. By Edward Barrett. New York: Henry Holt & Co. Pp. 386. Price, $2.

It was an excellent idea to get together in one compact volume the best thoughts of Carlyle, for there is a better and worse in his writings, as well as in those of all other authors. He has produced a lot of books in his day, unequal among themselves, but all containing, here and there, brilliant and powerful passages, well deserving to be thus separated and brought together for entertainment and edification at odd hours. We suspect, indeed, that Carlyle will be longer remembered for these strokes of extraordinary insight than on account of his elaborate works, in the great bulk of which there is a prodigious amount of wordiness—a fault which he so hated in other people. His works are mountainous, brilliant with gilded peaks, but with great stretches of valley between. It was not a bad idea of Barrett's to truncate the upper cones, and get the peaks all together in a single book, and, if Carlyle approves of it, as he says he does, and must do, all readers will be pleased.

New Encyclopædia of Chemistry. Chemistry, Theoretical, Practical, and Analytical, as applied to Arts and Manufactures. On the Basis of Dr. Muspratt's Work. Parts XV. to XX. Philadelphia: Lippincott & Co. Price, 50 cents per number.

We have already referred to this important work in very commendatory terms, and we may add that its character is well sustained to the later issues. It is not so much a dictionary of chemistry, in which the science is pulverized into a great number of fragments, and each placed under its alphabetical head, as a work in which the great leading subjects of chemical manufacture are taken up in succession, and treated in elaborate and exhaustive essays. The work is hence in no sense a rival of Watt's "Dictionary of Chemistry," which deals with the pure science rather than its practical applications to art and manufacture. The last installments treat of the subjects of dyeing and calico-printing, electro-metallurgy, enamels, ether, explosives, preservation of food, fuel, and gas. These topics are considered with fullness, and brought up to the latest results of scientific investigation.

Archology; or, the Science of Government. By S. V. Blakeslee, Oakland, California. New York and San Francisco: A. Roman & Co. Pp. 164. Price $1.25.

This is a very good little essay on government, but there is hardly enough science in it to justify the author in inventing a new term to describe it. He points out the great strides of the modern physical sciences, and contrasts with them the little that has been done of this kind in the fields of abstract thought, "especially in the all-important science of government."

He says, "This failure of a scientific treatment has been most remarkable;" and, as an attempt to remedy this defect by the development of a distinct science of government, the following treatise has been prepared. The little book is systematic and suggestive, and its matter is well presented; but the writer, in our opinion, has very little true conception of what science is in its applications to this subject.

The Plains of the Great West, and their Inhabitants. Being a Description of the Plains, Game, Indians, etc., of the Great North American Desert. By Richard Irving Dodge, Lieutenant-Colonel United States Army. With an Introduction by William Blackmore. Illustrated. New York: G. P. Putnam's Sons. Pp. 448. Price $4.

This is a lively, entertaining, and withal a very instructive volume on the Indians and Western life. Its author writes from observation and experience, and has a happy faculty of seizing the most striking and significant features in description, and representing them in vivid and forcible language. The work abounds in sketches of travel, delineations of camp-life, pictures of scenery, accounts of game, and episodes of sporting adventure. But its main and most important portion is that which is devoted to the religion, social life, habits, amusements, occupations, and what we may call the general natural history of the Indians. Appended to the volume is an instructive table of Indians living in the United States, omitting those in Alaska, with the numbers and locations of the tribes and fragments of tribes that still survive. The introduction by Mr. Blackmore gives some striking facts in regard to the destruction of the buffalo. He says that during the three years 1872–'74 four and a half million of these animals were destroyed, of which three million were killed merely for their hides. This is equal to the destruction of all the cattle in Holland and Belgium, and is as if in three years half the cattle of Texas, or all the cattle in Canada, had been carried off by a plague!

Mr. Blackmore quotes a passage from Bishop Whipple, on "Our Indian Policy," that furnishes an excellent example of the working of "American polities," and gives data by which we can compare the fruits of administration of the "best government on earth" with the miserable monarchy that rules on the other side of the St. Lawrence:

"One one side of the line is a nation that has spent $500,000,000 in Indian wars; a people who have not one hundred miles between the Atlantic and the Pacific which has not been the scene of an Indian massacre; a government which has not passed twenty years without an Indian war; not one Indian tribe to whom it has given Christian civilization; and which celebrates its centenary by another bloody Indian war. On the other side of the line are the same greedy, dominant, Anglo-Saxon race, and the same heathen. They have not spent one dollar in Indian wars, and have had no Indian massacres. Why? In Canada the Indian treaties call these men 'the Indian subjects of her majesty.' When civilization approaches them they are placed on ample reservations, receive aid in civilization, have personal rights in property, are amenable to law and protected by law, have schools, and Christian teachers send them the best teachers. We expend more than one hundred dollars to their one in caring for Indian wards."

The Applications of Physical Forces. By Amédée Guillemin. Translated from the French by Mrs. Norman Lockyer, and edited, with Additions and Notes, by J. Norman Lockyer, F. R. S. With Colored Plates and Illustrations. London: Macmillan & Co. Pp. 741. Price $12.

Five years ago a sumptuous volume appeared in Paris, by Amédée Guillemin, which was translated into English by the Lockyers, and republished by Macmillan, under the title of "The Forces of Nature." It aimed to be a popular account of the great physical forces, gravity, heat, light, and electricity. By the aid of numerous and finely-executed engravings, it attempted to make clear the principles of pure science with no reference to their uses or applications to the practical arts. A companion volume has now appeared by the same author, editor, and publishers, which supplements the first, by taking up the ap-

plications of physical forces. The book is done in the same splendid style, and we should wonder where so expensive and luxurious a scientific book could find buyers, did we not remember that the two editions in French and English make it accessible to the largest portion of the readers of the civilized world. It is difficult to convey a just idea of the scope and detail of this work, with its thirty-eight elaborate chapters and its four hundred and sixty-seven admirable illustrations, and we can only say that it is the most elegant and exhaustive pictorial work on the applications of science in its great leading departments that has yet appeared.

THE BENCH AND BAR OF SARATOGA COUNTY; or, Reminiscences of the Judiciary and Scenes in the Court-room from the Organization of the County to the Present Time. By E. R. MANN. Ballston, New York: Waterbury & Innman. Pp. 391. Price, $2.

BESIDES its waters, which are of interest to chemists, geologists, and invalids, and its gay summer life, so dear to the devotees of fashion, which combine to make Saratoga famous, the place is also celebrated for its lawyers. A county which has given to the bench such men as Cowen, Walworth, Willard, Bockes, and Spear, and to the bar such pleaders as Hill, Reynolds, Porter, and Beach, certainly deserves to have its legal history written out, and Mr. Mann has accordingly done it in a very creditable manner. In giving a sketch of the legal profession of the county, which has of course been closely associated with the growth of its population, the author has brought out various points of incidental interest. It appears that about 1790, before Saratoga Springs or Ballston Spa had yet been heard of, the town of Ballston included all the western and northern portions of the county, stretching away toward the Adirondacks. In that year two men, named Palmer and Gorden, were candidates for the supervisorship of this extensive region. The election for that spring was called to be held in the Milton Hill meeting-house. The day was bright and balmy, and so it was suggested that the election take place outside the church, and one of the justices, taking a suitable position, declared the polls open. The votes were taken *viva voce*, and "the people" went strongly for Gorden, who had been supervisor for several years before. Palmer, seeing he had no chance, drew off one of the justices, quietly went into the church and opened another poll, where thirteen men voted for him. The town-meeting had been appointed to be held *in* the church, and so Palmer was proclaimed unanimously elected by the citizens of Ballston. Gorden protested, but Palmer was "counted in," the same as nowadays. A feud followed between these office-seekers, the public espousing the causes of the rivals, and promoting their ambition. The knavish trick of the town-meeting ended in making both men county judges, and in sending each for two terms to the National House of Representatives. It is evident that Saratoga early furnished an excellent soil for the production of lawyers.

The first court-house and jail were erected at Ballston Centre, at a cost of $6,500, and were ready for use in 1796. Justice was dispensed there for twenty years, when it was burned down, with the following accompanying circumstances: Raymond Taylor, the jailer, was a man very full of the dignity and importance of his position, and would tolerate nothing that derogated from it in the prisoners under his charge. One named Billings had ruffled the jailer's complacency by some disrespectful words, and so Taylor had him securely fastened to the floor by a large ox-chain, riveted round his body by a blacksmith, and riveted also to the sill of the floor. Another prisoner set fire to the wall of his cell to burn his way out, and, as the flames rapidly extended, efforts were made to rescue Billings, but they could not loosen the chain, and so he was consumed with the burning court-house. As a further illustration of how modern politics is developed from its early germs, it may be stated that there was a law forbidding the jailer to furnish the prisoners with lights, so Taylor arranged with another man to furnish them, and divided the profits.

In a history of nearly a hundred years, only two men have been publicly strangled in Saratoga County in the interest of justice, and the first of them, hanged in 1820,

is said by the author of this work to have been insane.

The chief contents of the volume, consisting of personal sketches, anecdotes, and accounts of lawsuits, are, as might be expected, only of local interest.

The Art of Projecting. A Manual of Experimentation in Physics, Chemistry, and Natural History, with the Porte-Lumière and Magic Lantern. By Prof. A. E. Dolbear, Tufts College. Illustrated. Boston: Lee & Shepard. Pp. 158. Price $1.50.

This is a valuable little volume for all teachers and professors who desire to cultivate the art of illustrating their numerous scientific subjects by the projection of optical images of objects upon screens for the inspection of classes, or lecture-room auditories. Full attention is first given to the construction of apparatus, much of which, the author says, can be extemporized; and the author then points out how a surprisingly large number of experiments can be performed with these instruments in numerous departments of science and art. The book is full of neat woodcuts which aid the text in the description of operations, and it seems a thoroughly well-executed manual for helping on the work of scientific instruction.

A Text-Book of Physiology. By M. Foster, M. A., M. D., F. R. S., Prælector of Physiology, and Fellow of Trinity College, Cambridge. New York: Macmillan & Co. Pp. 559. Price, $6.

Dr. Michael Foster has here given to the world a first-rate book on physiology. He is a good investigator, and a clear, pointed, and vigorous writer, and, with excellent scientific judgment in presenting the proportions of a subject, he has prepared a volume trustworthy in exposition and agreeable in its style. It is designed for medical students, and does not aim to be elementary, as the author proposes to begin about where Prof. Huxley's physiology leaves off. In fact, he hopes his book may come to be considered as a kind of advanced companion to Huxley's smaller volume.

The work contains a few simple diagrams, but it cannot be said to be illustrated, and herein we are inclined to think the author has made a serious mistake. His reasons for it are as follows: "I have, moreover, given neither figures nor elaborate descriptions of physiological instruments and apparatus. These must be seen, not read about; the student can learn more by five minutes' inspection of a piece apparatus, especially one at work, than by hours of study of even the most expensive and finished pictures, and most detailed verbal descriptions." True, but shall we therefore give up illustrations? It is always better to see the thing itself, and it should be the first law of education to get at the thing itself, and not take a picture in place of it, *wherever that can be done*. But then figures do no harm; they may be still helpful to those who have had the opportunity of inspection, while in the case of multitudes who have no such chance the pictures are much better than nothing. No one can look over the fine and accurate illustrations of such a work as Flint's "Manual of Physiology," for example, without recognizing the great advantage that most students will gain by referring to them.

The Fleets of the World. The Galley Period. By Foxall A. Parker, Commodore of U. S. Navy. New York: D. Van Nostrand. Pp. 235. Price, $5.

This neat and elegantly-illustrated volume is a kind of introduction to the history of naval warfare. It is devoted to an account of sea-fights in old times, and it cannot fail to be very interesting to all who have a concern in the subject. We have greatly admired the finely-executed illustrations of the lubberly old ships that were employed before the improved modern craft came into use.

PUBLICATIONS RECEIVED.

The Microscopist: A Manual of Microscopy. By J. H. Wythe. Third edition, rewritten and enlarged. Pp. 259. With Plates. Philadelphia: Lindsay & Blakiston. Price, $4.50.

Michigan State Board of Health, 1876. Pp. 254. Lansing: W. S. George & Co. print.

Acoustics, Light, and Heat. By William Lees, A. M. Pp. 299. New York: Putnams. Price, $1.50.

Smithsonian Report, 1875. Pp. 422. Washington: Government Printing-Office.

Properties of Continuous Bridges. By C. Bender, C. E. Pp. 150. Boiler Incrustation. By F. J. Rowan. Pp. 88. New York: Van Nostrand. Price, 50 cents.

"The Jukes:" A Study in Crime, Pauperism, etc. By R. J. Dugdale. Pp. 118. New York: Putnams. Price, 50 cents.

Origin of the Chinese Race. Pp. 30. Japanese Wrecks in the North Pacific. Pp. 23. Early Maritime Intercourse of Ancient Western Nations. Pp. 13. By Charles Wolcott Brooks. San Francisco: Reprinted from the Proceedings of the California Academy of Sciences.

The Stone Age in New Jersey. By Dr. C. C. Abbott. Pp. 134. With numerous Plates. Washington: Government Printing-Office.

The Science of Astronomy. Lecture by A. K. Bartlett. Pp. 36. Battle Creek, Mich.: The Author. Price, 50 cents.

Analysis of Milk. By E. von Baumhauer. Pp. 34. New York: J. F. Trow & Son print.

Wisconsin Geological Survey for 1876. By T. C. Chamberlin. Pp. 40. Madison: S. D. Carpenter print.

The *Chinese Scientific Magazine*. Monthly. Vol. I., No. 10. John Fryer, Editor, Shanghai (printed in Chinese). Price, 50 cents per annum.

Addresses before the St. Louis Academy of Science. By C. V. Riley. Pp. 16. St. Louis: R. R. Studley & Co. print.

The Index. Containing classified Index of Periodical Literature. Monthly. Pp. 16. New York: William Erving. Price, $1.00 a year.

Theory of the Radiometer. By William Crookes, F. R. S. Pp. 16. London, 1877.

Minnesota Normal School Board for 1876. Pp. 40. St. Paul: *Pioneer Press* print.

Polar Colonization. By H. W. Howgate. Pp. 40. With Chart. Washington: Beresford print.

Zoölogical Society of Cincinnati. First, Second, and Third Annual Reports. Cincinnati, O.: Printed for the Society.

Common-School Education. By B. A. Hinsdale, A. M. Pp. 38. Cleveland, O.: Robinson, Savage & Co. print.

Metric System of Weights and Measures. Pp. 12. Boston: The Society of Civil Engineers.

Vitality of Certain Land-Mollusks. By R. E. C. Stearns. Pp. 2. With Plates. From the Proceedings of the California Academy of Sciences.

Report of the Commissioners of the State Survey for 1877. Albany: Parmenter print.

Outlines of Field Geology. By Prof. Geikie. Pp. 61. Price, 25 cents. Absorption of Light. By Prof. Stokes. Pp. 43. Price, 20 cents. London and New York: Macmillan.

Excrescences and Eccentric Wood-Growths in the Trunks of Trees. By Thomas Meehan. Pp. 6. From the Proceedings of the Philadelphia Academy of Natural Sciences.

Milk-Adulteration in the New York Courts. Pp. 32. New York: J. F. Trow & Son print.

POPULAR MISCELLANY.

Tyndall and Roberts on Spontaneous Generation.—Dr. Bastian, in a communication to the Royal Society of London, last June, cited some experiments to show that, while an acid urine usually remains barren after being boiled a few minutes, it becomes fertile when similarly treated if previously neutralized by liquor potassæ, especially if it be afterward maintained at a temperature of 115° or 120° Fahr. But the significance of these results for the doctrine of spontaneous generation is proved to be very little indeed by Dr. William Roberts and Prof. Tyndall, both of whom show that Bastian's experiments only confirm the observation made by Pasteur more than fourteen years ago, that alkaline liquids are more difficult to sterilize than acid ones. They further show that such liquids, once effectually sterilized, according to methods which they describe, remain perfectly sterile when the access of life-germs from without is precluded. The addition of the alkali appears to enable the preëxisting germs in the urine to survive the process of ebullition. To prevent this conservative action of the liquor potassæ, and at the same time to have a mixture precisely the same as that experimented on by Bastian, Tyndall adopted the following mode of procedure, which is substantially identical with that adopted by Dr. Roberts: Small tubes, with their ends finely drawn out, were charged with a definite amount of caustic potash, and subjected for a quarter of an hour to a temperature of 220° Fahr. They were then introduced into flasks containing measured quantities of urine. The urine being boiled for five minutes, the flasks were hermetically sealed during ebullition. They were subsequently permitted to remain in a warm

place sufficiently long to prove that the urine had been perfectly sterilized by the boiling. The flasks were then rudely shaken, so as to break the capillary ends of the potash-tubes and permit the liquor potassæ to mingle with the slightly acid liquid. The urine thus neutralized was subsequently exposed to a constant temperature of 122° Fahr., which is pronounced by Dr. Bastian to be specially potent as regards the generation of organisms.

Ten flasks, prepared as above described toward the end of last September, remained perfectly sterile for more than two months. There is no doubt that they would have remained so indefinitely.

Three retorts, moreover, similar to those employed by Dr. Bastian, and provided with potash-tubes, had fresh urine boiled in them on the 29th of September, the retorts being sealed during ebullition. Several days subsequently, the potash-tubes were broken, and the urine neutralized. Subjected for more than two months to a temperature of 122° Fahr., they failed to show any signs of life.

The Phenomena of Hypnotism.—Dr. Heubel, in *Pflüger's Archiv*, rejects Czermak's explanation of hypnotism (*see* The Popular Science Monthly, vol. iii., p. 618, vol. iv., p. 75), as also the explanation offered by Kircher and Preyer, and thinks that all previous investigators of this phenomenon have witnessed only its first stage—that which is most easily induced in animals of relatively high organization. Cold-blooded vertebrates, such as the frog, may be reduced to a state of complete immobility at will; they will remain in a constrained position for hours, instead of seconds or minutes. This abolition of voluntary movement and of consciousness is, according to the author, nothing but ordinary sleep. He holds that the waking state requires for its maintenance a continual stimulation of the higher nervous centres by impressions conveyed to them along the various centripetal nerve-fibres. By forcing an animal to remain motionless for a brief interval (without inflicting pain), and simultaneously excluding visual and auditory sensations from its brain, we suddenly deprive its nerve-centres of a large proportion of their accustomed stimuli. Accordingly, they are unable to remain awake, and their functional activity is only restored to them when they are roused by some impulse from without. Having satisfied himself in a variety of ways of the correctness of this explanation as applied to the phenomena exhibited by the frog, Heubel proceeds to extend his results to birds and mammals, and arrives at the conclusion that "forced sleep" will account for all the facts hitherto observed.

Further Experiments with Putrescible Fluids.—Mr. Dallinger has communicated to the Royal Microscopical Society of London some further results of his experiments with sterile putrescible fluids. In these experiments, an air-chamber after Tyndall's plan was used, and it was tested for motes by a beam of oxyhydrogen-light. The germs were obtained from a maceration of haddock's head that had been kept for fifteen months, and found to contain numbers of the "springing and calycine monads" of former papers, many of them in a condition for emitting spores. A portion of this material was evaporated at the temperature of 150°. Dust from it was diffused through the Tyndall chamber, and, after the heavier particles had settled, in the course of four and a half hours, ten small glass basins filled with Cohn's nutritive fluid, freshly prepared, were introduced, six being open and four covered with glass lids. In this condition they were left for twenty-four hours, and then the lids were removed from the four covered vessels. After four days, "calycine" monads were found in all the first six vessels, and, in smaller numbers, the "springing" sort. Two days later the four vessels were examined; in three there were no calycine monads, and very few in the fourth; all exhibited the springing monads. The reason of this is probably to be found in the fact that the germs of the calycine monads are larger than those of the springing sort, and settled down first from their state of suspension in the air.

A Solar Distillery.—M. Mouchot lately described, at a meeting of the Paris Academy of Sciences, a very convenient solar alembic. The mirror is fifty centimetres in diameter, and the kettle holds one litre of

wine, which begins to boil on being exposed to the sun for not over half an hour. The vapor of alcohol is then condensed in a worm. The brandy thus obtained is very agreeable in flavor, no matter what kind of wine is used. It possesses an aroma resembling that of Kirschwasser. "It suffices," adds M. Mouchot, "to fill the kettle with water, and then to interpose between it and the worm a receptacle containing sweet-smelling leaves and flowers, in order to obtain all the essences yielded by distillation."

The Florida Cockroach new to American Science.—It is somewhat remarkable that, in certain parts of Florida, living is made almost impossible from the presence, in amazing numbers, of a cockroach not known North. The queer thing is that, while this pest has been long known in Florida, the fact has escaped the knowledge of scientific men. Mrs. Treat lately sent specimens to Prof. S. H. Scudder, the orthopterist, who was surprised to see them, and pronounces them the *Periplaneta Australasia* of Fabricius.

Meteorological.—A sixth paper by Prof. Loomis is published in the *American Journal of Science* for January, giving "results derived from an examination of the observations of the United States Signal Service." The object of this important series of papers is to generalize results, using as data the vast amount of observations made in all parts of the United States.

In this paper, Prof. Loomis considers first the period of unusual heat which occurred in June, 1873. The thermometer rose to 108° at one point—Fort Sully—and to 95° and 100° at other points, for several days in succession, indicating a temperature 20° above the mean for the month. The heated area was north of latitude 39°, and east of the Rocky Mountains, and advanced slowly eastward to Western New York.

It appears that the heat was over a well-defined area, which was also an area of depressed barometer. There was also a gentle movement of air from the south into that area, which accounts for some of the excess of heat; but the region where it arose—Colorado, Montana, and contiguous districts—was excessively dry. No northern winds occurred to cool the air, and Prof. Loomis thinks the great excess of heat may be attributed to the hot south winds already referred to, and, secondly, to the accumulated effects of the sun's radiation.

In the second part of the paper the movements, form, and distribution of rain areas south of latitude 36° are considered. When two or more inches of rain falls within eight continuous hours, we have a "great rainfall." It appears that such rainfalls do not usually continue more than eight hours, and only very rarely do they continue twenty-four hours, either at one station or at successive stations.

It is shown that, on the Gulf and Atlantic border, the great rainfalls are twice as frequent on the coast as at 200 miles inland from it. A cause assigned is the rising of the air from the ocean as it impinges upon the land, and the consequent condensation of its vapor. This movement of the air assumes a cycloidal direction, as was found to be the case in a great number of instances, the motion being from right to left, in the direction contrary to that of the hands of a watch. "Hence, every great rain-storm should be accompanied by an inward and cycloidal motion of the air."

In the distribution of fifty-two cases of great rainfall by seasons, it was found that forty occurred in summer and autumn to twelve in winter and spring. Northward of latitude 36° the difference was still greater, being as five to one. It is thus shown that great rainfalls are most frequent when the sun's heat is greatest, and the air contains most vapor.

The hours of the day have a direct relation to great rainfalls. Thus, they most frequently occur before 4.35 P. M., and seldomest at 11 P. M.; only eight out of fifty-two instances are reported by the night observations made at 11 P. M.

The area of greatest rainfall is found to be within that of the cycloidal movement of air, but not at the centre of low pressure. It is almost invariably eastward from it, sometimes more than 250 miles. Thus, a storm-area, as previously shown by Prof. Loomis, usually assumes an oblong shape, the long radius of which is ahead of the

storm, in or near the general direction of its motion.

At stations northward of latitude 36°, observations show that great rains are accompanied by easterly winds; but, at the more southern stations of the district, the winds are north of east; while, at the northern stations, the winds are from south of east. When the wind blows from any other quarter, it is usually light.

This paper, like others previously published, presents, with the diagrams which have been published with them, the general phenomena of atmospheric movements with clearness and precision, and will speedily supersede the vague speculations concerning them which have so much occupied the public mind.

A Rapacious Fish. — The *Serrasalmo piraya*, found in all the rivers of Guiana, is doubtless one of the most voracious of fishes. The genus *Serrasalmo* (literally "serrated salmon," because of the double row of serratures on the belly) can hardly be classed with *Salmonidæ*, from which they differ both in general appearance and in habits. The *S. piraya* is a small fish, seldom exceeding one foot in length, but yet there is no animal that it will not attack, man not excepted. Alligators, horses, as well as fishes oftentimes ten times their own weight, are preyed upon by the pirayas. In attacking a fish they begin at the caudal fin, and the victim, being thus left without the principal organ of motion, is devoured with ease, several pirayas sharing in the meal. They often bite a piece out of a horse's leg when passing through the water. The feet of ducks and geese which are kept in the neighborhood where pirayas are plentiful, are almost invariably cut off, and the young ones devoured. In such localities it is unsafe to bathe, or even to wash clothes, in the river, many cases having occurred of fingers and toes being cut off by them. Schomburgck, in his "Travels in South America," from which most of these particulars have been derived, states that these fishes are "caught with hook and line, and their greediness is so great that no art is necessary to conceal the bait. The hook may be baited with a piece of fish, bird, or animal, or merely their entrails; the piraya will dart at it the instant it is thrown into the water, and seize it with eagerness, but it frequently happens that with its sharp teeth it bites the line, and escapes with the hook in its mouth. We, therefore, surrounded the line where it was fixed to the hook, the length of two or three inches, with tin or lead, and though it had a clumsy appearance we were not less successful. Some precaution is necessary even after the fish has been lifted out of the water, or it will inflict in its struggles serious wounds; the angler has, therefore, a small bludgeon ready, wherewith its skull is broken."

Science and Ventilation.—Sundry members of the Paris Academy of Sciences, at a recent session, expressed themselves very strongly as to the defective ventilation of the hall in which their meetings are held. Said M. Bouley: "The air here is unfit to breathe; the thing admits of no excuse; instead of gas, I wish we had again candles, as in former times." M. Leverrier: "I asked for lighting with gas, but I had also asked for another mode of ventilation; but, with regard to this, there has been no change. However, General Morin is a member of the Academy, and, in eight days, proper apparatus for ventilation might be set up, if we so wished." General Morin: "Eight days! Ten years ago, the setting up of such apparatus was in principle decided on." Leverrier: "The present condition of things is simply disgraceful; no other hall is so badly ventilated as the hall of the Institute." The eminent astronomer, were he to inspect critically the assembly halls of scientific and legislative bodies in other countries, would doubtless find abundant reason for retracting this severe judgment.

Intestinal Calculi in Horses.—In England and Continental Europe large numbers of horses die annually from the effects of calculi in the large intestine or in the cæcum. Of these calculi, Dr. T. L. Phipson writes in the *Chemical News* that they often begin by being triangular, or sometimes perfectly square, with rounded edges and corners, and become finally circular. In all cases they are formed of highly-crys-

talline concentric layers, and attain to eighteen or twenty inches in diameter. This, he thinks, is the greatest size they can attain. When so large as this, they press out the sides of the intestine, producing inflammation and violent pain, which causes the animal to roll about in agony, and, sooner or later, kills him. They consist mostly of phosphate of ammonia and magnesia, and the amount of organic matter is not great. This salt the author refers to the grain fed to the animals, and he raises the question whether grain is not for the horse a highly-artificial food. He is of the opinion that repeated doses of very dilute hydrochloric acid, say two to five per cent., in water or spirit, if it can be made to reach them, would quickly destroy the largest of these calculi. The lime in the water drunk by horses has nothing to do with the production of these concretions. It originates in the food, and is, in a large measure, due to a want of salt in the grain. Hence, working-horses that are highly fed should have lumps of salt to lick, and have salt in their food, and plenty of water to drink. The ventilation and drainage of stables is another important consideration. Many valuable beasts, after a hard day's work, pass the night in an atmosphere loaded with fumes of ammonia.

Abnormal Fruits.—Some abnormal fruits of the pear-tree, in appearance like very large acorns, having been exhibited at a meeting of the Academy of Natural Sciences of Philadelphia, Mr. Meehan took occasion to explain that a fruit is a modification of both leaves and branch. When a bud, he said, is being formed in the apple, pear, or similar trees, it may finally be either a flower-bud or a bud producing a new branch. Varying phases of nutrition decide this question. Exactly the nature of this variation we do not know; but we do know that the growth-force in the bud is arrested by some law of nutrition, and, instead of an elongated branch, what would be its series of spirals are drawn together closely, and the whole modified and made to form a flower. Thus, in the pear, it takes five buds to form one full cycle on a branch. When growth is arrested to form a flower, this first cycle is transformed into a five-lobed calyx, and generally this becomes much enlarged and fleshy, and covers all the other cycles of buds, which go to make up the inner layer of flesh terminating in the petals, carpels, or core, and so on. In the case under consideration the arresting force was imperfect. It had succeeded in forming the outer or calycine verticillate series of buds into a fleshy matter, giving what here might be called the cup of the "acorn;" but then the accelerating or branch-producing force gained a temporary advantage, and pushed on, forming the acorn-like centre, but only to be soon again arrested. This abnormal pear was, indeed, nothing more than an effort of the tree to produce a branch after a fruit had been decided on—a struggle which was finally decided in favor of the fruit.

Explanation of the Ball-Paradox.—Reuleaux offers the following explanation of the curious phenomenon of a ball being supported in air by a strong air-current directed obliquely upon it at an angle of 35° to 40° from the vertical: The pretty thin air-current, on reaching the ball, is deflected on all sides, and therefore more or less rarefied in its interior. Accordingly, the atmosphere presses the ball in the direction of greatest rarefaction, or the mean force of the rarefactions, toward the orifice. The weight of the ball acts vertically downward. Equilibrium occurs between the obliquely acting force of the current and the two forces just named, when the mean force of the latter is parallel to the action of the current. This can only take place when the ball has its centre under the axis of the current. There are then two forces which put the ball in rotation. If the finger or a rod be brought to the place of supposed minimum pressure on the ball, the latter is forthwith driven off (the vacuum being destroyed), or falls down.

Successful Case of Transfusion of Blood.—A case of successful transfusion of blood is recorded in the *Lancet*. The patient, a clerk, twenty years of age, was completely demented, hyperæmic, anæsthetic, and cataleptic; refused all food; dribbled constantly. The pulse was very feeble, rate 70, respiration 24. His state was one of profound

anæmia. A student in St. Thomas's Hospital volunteered to supply the blood for the operation. The patient received 200 grammes of blood without showing any bad symptoms; he even gave evidence of being roused from his habitual torpor. Three hours after the operation, the patient, who had, in the mean time, been placed in a warm bed, and had taken doses of tea and brandy, had a full pulse, rate 90, respiration 28. He answered to his name and spoke a few words, rubbed his face with one of his hands, opened his eyes, and swallowed voluntarily. Five hours later the pulse was 100, strong, respiration 30. The following day the pulse was 96 and respiration 28, and the patient ate and drank well and often. Toward evening the pulse was 90, respiration 28, and he spoke and answered slowly when spoken to; said he had no pain. Four days later the symptoms still continued to be favorable. The process of transfusion was to be repeated by the physicians, the results being so encouraging.

Production of Sulphurous Acid for Use as a Disinfectant.—Sulphur-fumes (sulphurous acid) have from time immemorial been employed to fumigate and purify infected air, but the ordinary method of producing the fumes by burning sulphur is cumbrous and very uncertain. Mr. T. W. Keates offers in the *Lancet* a ready and simple means of effecting this object. Instead of sulphur, he proposes to use bisulphide of carbon, a compound consisting of two atoms of sulphur and one of carbon. It is a dense, mobile liquid, heavier than water, and intensely inflammable. During combustion the constituents of the bisulphide combine with the oxygen of the air, producing sulphurous and carbonic-acid gases, the former greatly exceeding the latter in quantity. The bisulphide can be burned in a common spirit-lamp, or it may be mixed with oils and burned in an oil or kerosene lamp. Any proportionate quantity of sulphurous acid can in this way be thrown into an atmosphere, and the action may be continued for any length of time. As bisulphide of carbon is extremely volatile, the lamp should be furnished with a well-fitting screw-cap, to prevent loss by evaporation.

A Fishing-Spider.—"Just before the late war," writes the author of a communication in the *American Naturalist*, "I was at Colonel Oakley Bynum's spring, in Lawrence County, Alabama, near the town of Courtland, where I saw a school of minnows playing in the sunshine near the edge of the water. All at once, a spider, as large as the end of my finger, dropped down among them from a tree hanging over the spring. The spider seized one of the minnows near the head. The fish thus seized was about three inches long. As soon as it was seized by its captor, it swam round swiftly in the water, and frequently dived to the bottom, yet the spider held on to it; finally, it came to the top, turned upon its back, and died. It seemed to have been bitten or wounded on the back of the neck near where the head joins. When the fish was dead, the spider moved off with it to the shore. The limb of the tree from which the spider must have fallen was between ten and fifteen feet above the water. Its success shows that it had the judgment of a practical engineer."

Qualitative Determination of Potassa.—Carnot offers a new and simple process for the qualitative detection and the determination of potassa, hitherto one of the most delicate operations in analytical chemistry. It is as follows: In a few drops of hydrochloric acid, one part of the subnitrate of bismuth, say half a gramme, is dissolved, and then, in a few cubic centimetres of water, are dissolved about two parts (one gramme to one and a quarter) of crystallized hyposulphite of soda. The second solution is poured into the first, and concentrated alcohol added in large excess. This mixture is the reagent. If brought in contact with a few drops of the solution of a potash salt, it at once gives a yellow precipitate. With an undissolved potassic salt it produces a decidedly yellow coloration, easily recognized. All potassic salts with mineral acids are susceptible of this reaction; it is also very sensitive with the organic salts—tartrates, citrates, etc. The reaction is not interfered with by the presence of other bases, with which nothing analogous is produced. The character is therefore perfectly distinct. Baryta and

strontia alone may occasion some difficulty by reason of the white precipitates of double hyposulphites, which they form with the same reagent; but it is very rare to meet them along with potassa, and they are very easily detected and removed.

Prevention of Fires in Coal-Mines.—In an address on fires in mines, Mr. Richard P. Rothwell affirms that the most efficient preventives of such fires, from whatever cause they may come, are to be found in education, in increased knowledge of the causes of fires, and a better appreciation of the working of these causes. Mine-managers he would compel to undergo strict examinations, nor would he allow any one to undertake the responsible duties of this place without a certificate of competency from a qualified board of examiners. He would not, however, stop here, but would have the miners themselves instructed as to the causes and preventives of the dangers they meet with in their work. Special free instruction upon these points might be furnished at every colliery; and this could doubtless be accomplished by encouraging the giving of popular lectures, by practical miners and engineers, on subjects of interest to the miner, and by giving small prizes to those who pass the best examination on subjects of daily practical application in their calling. Greater knowledge always makes better workers, and mine-owners would find in this a good return for the expense incurred.

Economy of the Electric Light.—In a series of experiments on electric light, Prof. W. A. Anthony used an electro-magnetic machine of the Gramme pattern, driven by a five-horse Brayton petroleum-engine. The engine consumed a little over 6½ pounds of crude petroleum per hour. The lamp used in the engine, by which the explosive mixture is fired, had a one-inch flat wick, and consumed 29.8 grammes (459 grains) of oil per hour. The power resulting from the motion of the engine, when applied to the electric machine, produced a stream of electricity or electric light having an illuminating power equal to that of 234 of the lamps mentioned, showing that three times more light may be produced from a given quantity of oil, if its energy is converted first into mechanical power and then into electricity, than if the oil is directly burned in a lamp.

Southern Illinois Academy of Science.—The Southern Illinois Academy of Science, a newly-founded scientific association, with its seat at Carbondale, has for its objects the investigation—1. Of the ethnology and history of Southern Illinois, including its antiquities and aboriginal remains; 2. The geology, botany, and zoölogy, of that section; and, 3. To encourage the production of original papers on the above, and on special mathematical, astronomical, and meteorological subjects, as well as on the origin and meaning of the names given to localities by the Indians and the first white settlers of the country. The Academy is engaged in making a collection of materials illustrative of the field of research to which it has devoted itself, and has issued a circular calling for contributions of archæological and aboriginal remains, historical notes, maps, sketches of mounds, natural history specimens, etc. The Secretary of the Academy is Prof. Granville F. Foster, Carbondale, Illinois.

Threatened Eruption of Mount Vesuvius.—For many weeks Mount Vesuvius has been threatening an eruption. Prof. Boyd Dawkins, who visited the volcano in January, found, on arriving at the mouth of the crater, that it was filled with dense vapor like a fog. A low, roaring noise could be heard, and occasionally there was a flash of light, probably the reflected glare of the lava surging about in the volcano. Undismayed by these symptoms of internal disturbance, Prof. Dawkins went down seven or eight feet below the crater's edge, and found that he could light pieces of paper in holes which he dug with his hammer in the black ash on the inside. He is of the opinion that Vesuvius performs the duty of a safety-valve to a very large portion of the earth. At present the mountain is in a very restless state, and there may be an outbreak at any moment. The event is looked for with great interest by the inhabitants of Naples, as it will bring sight-seers from all parts of the world to their city.

The Challenger Collection.—The collections of marine animals made by the Challenger Expedition are declared by Prof.

Agassiz to be in a better state of preservation, and their localities more accurately noted, than is the case with any similar collection he has seen. To give an idea of the magnitude of the Challenger collections, he says that if a single individual, possessing the knowledge of the eighteen or twenty specialists in whose hands they are to be placed, were to work them up, he would require from seventy to seventy-five years of hard work to bring out the results which the careful study of the different departments ought to yield. At the same time Prof. Agassiz observes that little that is new has been added by the Challenger Expedition to the deep-sea fauna as developed by the American and English Expeditions of 1866 and 1869. Reasoning from these premises, "we may safely say that while any new expeditions will undoubtedly clear up many of the points left doubtful by the Challenger, and may carry out special lines of investigation only partly sketched out, yet we can hardly expect them to do more than fill out the grand outlines laid down by the great English Expedition."

Preservation of Ice in the Sick-Room.—Dr. Gamgee, in the *Lancet*, suggests a good method of preserving ice in small quantity for a considerable time at the bedside of a sick person. His practice is to cut a piece of flannel about nine inches square, and secure it by ligature round the mouth of an ordinary tumbler, so as to leave a cup-shaped depression of flannel within the tumbler to about half its depth. In the flannel cup so constructed pieces of ice may be preserved many hours, all the longer if a piece of flannel from four to five inches square be used as a loose cover to the ice-cups. Cheap flannel, with comparatively open meshes, is preferable, as the water easily drains through it, and the ice is thus kept quite dry. When good flannel with close texture is employed, a small hole must be made in the bottom of the flannel cup, otherwise it holds the water, and facilitates the melting of the ice. In a room with a temperature of 60° Fahr., Dr. Gamgee made the following experiments with four tumblers, placing in each two ounces of ice broken into small pieces. In tumbler No. 1 the ice was loose. It had all melted in two hours and fifty-five minutes. In tumbler No. 2 the ice was suspended in the tumbler in a cup made, as above described, of good Welsh flannel. In five hours and a quarter the flannel cup was more than half filled with water, with some pieces of ice floating in it; in another hour and a quarter the flannel cup was nearly filled with water, and no ice remained. In tumbler No. 3 the ice was suspended in a flannel cup made in the same manner and of the same material as in No. 2; but in No. 3 a hole capable of admitting a quill pen had been made in the bottom of the flannel cup, with the effect of protracting the total liquefaction of the ice to a period of eight hours and three-quarters. In tumbler No. 4 the ice was placed in a flannel cup made, as above described, of cheap, open flannel, which allowed the water to drain through very readily. Ten hours and ten minutes elapsed before all this ice had melted.

Grote's Theory of the Peopling of America.—Prof. Grote's theory of the original peopling of America, as stated in recent papers, is that the original inhabitants came from Asia by way of the north during the latter part of the Miocene or earlier part of the Pliocene, and that this Tertiary population spread to the south along the mountainous backbone of the two Americas; that, on the advent of the Glacial epoch, the people then living in the extreme north were modified by the change in climate and were brought down by the ice and followed it back again to the arctic circle, and that the present representatives of glacial man are the Esquimaux. Through a study of migrations Prof. Grote comes to the conclusion that the ice must have acted as a barrier to further communication between the two continents of Asia and North America, and consequently that the civilizations of Central America and of the mound-builders are indigenous. Grote concludes that the theory of an accidental migration from Asia during the Quaternary cannot be supported in view of recently-ascertained facts. In a letter dated February 11, 1877, Captain E. L. Berthoud (of the School of Mines at Golden, Colorado), who has studied the geology and archæology of the West since 1859, writes that Grote's theory "solves many knotty points in the antiquities and

prehistoric vestiges of Colorado." Captain Berthoud believes, from his observations, that man existed in the Rocky Mountain region prior to the deposit of gold in the Colorado mountain-slopes, Creek, Bar, and Placer diggings, about latitude 39° 30′ to 41° north. Captain Berthoud has not only found flint tools and chips in the gold-bearing glacial drift, with remains of fossil elephants, but also in the drift of older date below this gold-bearing drift. Flint tools have been also found in company with estuary shells of not later age than older Pliocene as determined by Prof. Conrad.

The Decline of Savage Races.—Virchow, in an address upon the present position of anthropology, makes a few very just observations upon the subject of the decline of savage races in the presence of civilized man. Thus he remarks that we must not, in the case of an entirely isolated people, judge of their capacity for culture from the signs of it which exist. The extinction of uncultured races, he thinks, is rather to be ascribed to the barbarousness of Europeans, and to their incapacity to educate savages. There is no evidence that uncivilized races must become extinct—indeed, the contrary is proved by the history of Europeans themselves. If the civilized people of the present day are the product of a higher development, we cannot regard the possibility of such a development as a cause of the extinction of races in the same stage of culture once occupied by ourselves.

Estimation of Alcohol in a Watery Mixture.—Dr. Werner Siemens has designed an ingenious apparatus, by which a stream composed of alcohol and water, mixed in any proportion, is so measured that one train of counter-wheels records the volume of the mixture, while a second counter gives a true record of the amount of absolute alcohol contained in it. The principle is described as follows: The volume of liquid is passed through a revolving drum, divided into three compartments by radial divisions, and not dissimilar in appearance to an ordinary wet gas-meter. The revolutions of this drum produce a record of the total volume of passing liquid. The liquid on its way to the measuring-drum passes through a receiver containing a float of thin metal filled with proof-spirit, which float is partially supported by means of a carefully-adjusted spring, and its position determines that of a lever, the angular position of which causes the alcohol-counter to rotate more or less for every revolution of the measuring-drum. Thus, if water only passes through the apparatus, the lever stands at its lowest position, and then the rotative motion is not communicated to the alcohol-counter, and this motion is rendered strictly proportionate to the alcohol contained in the liquid, allowance being made in the instrument for the change of volume due to chemical affinity between the two liquids.

Preservation of Iron against Rust.—We find in *Van Nostrand's Engineering Magazine* an account of Dr. William H. Sterling's process for preventing the rusting of iron. The principle of this system, we are informed, consists in the saturation of the iron with a non-oxidizing or non-oxidizable substance while the iron is in a properly heated and expanded condition, produced by heating in a vacuum or in a simple chamber. One method of applying this system is given as follows by the inventor: "A vessel of iron, or any suitable material of sufficient strength, is made in the form and size best adapted to the shape and dimensions of the iron which is to be treated, with the lid so constructed that the vessel may be closed hermetically, and at the bottom suitable pipes are arranged for conveying steam and water alternately, for the purpose of heating and cooling the interior." Suitably connected with this vessel is a power-pump to produce the necessary pressure, also appliances for obtaining a vacuum. The iron is now heated to the desired degree and placed in the vessel, the top closed hermetically and superheated steam turned into the pipes at the bottom, to keep the metal at the required temperature; at the same time an atmospheric vacuum is produced by an ordinary air-pump connected with the chamber; the proper quantity of pure paraffine, having been also previously heated, is now let into this chamber and forced under pressure into

the interstices of the iron, saturating it. When the iron has remained under this liquid pressure a sufficient time, it is gradually cooled by turning cold water instead of steam into the pipes, the pressure being kept up, however, until the iron is cool.

Destruction of Birds by Telegraph-Wires.—It is the opinion of Dr. Elliott Coues that in the United States many hundred thousands of birds are yearly killed by telegraph-wires. To show that this estimate is not extravagant, he cites his own observation while journeying on horseback from Denver, Colorado, to Cheyenne, Wyoming, the road for a considerable part of the way coinciding with the line of the telegraph. The most abundant birds of that region at the time (October) were horned larks and Maccown's bunting. "Almost immediately upon riding by the telegraph-wire," writes Dr. Coues in the *American Naturalist*, "I noticed a dead lark; and as I passed several more in quick succession, my attention was aroused. The position of the dead birds enabled me to trace cause and effect before I actually witnessed a case of the killing. The bodies lay in every instance nearly or directly beneath the wire. A crippled bird was occasionally seen fluttering along the road. Becoming interested in the matter, I began to count, and desisted only after actually counting one hundred in the course of one hour's leisurely riding—representing perhaps a distance of three miles." During the hour he saw three birds strike the wire; of these one had a wing broken, and another was dying in convulsions.

Natural History on the Great Lakes.—Prof. Comstock, of Cornell University, proposes to organize an aquatic school of natural history for work during the summer along the shores of Lakes Erie, Huron, and Superior. A steamer is to be chartered for the use of the school, and inland excursions are to be made to the mining regions and other points of scientific interest. A strong corps of instructors for zoölogy, botany, geology, etc., will be engaged, and collections will be made illustrative of the work done in these various departments. A portion of the collection will be the property of the students, while the remainder will be disposed of to such local societies, colleges, and schools, as may desire to purchase them in advance by taking shares at $10 each. The terms for admission to the school are very reasonable, viz., not to exceed $125 for thirty days, and $3.50 for each additional day. This, however, does not include the expenses of inland trips: such trips will only be made by such pupils as desire to take part in them, and will be so arranged as to require the least possible expenditure.

Winter-Quarters in the Arctic Regions.—The ship Discovery, of last year's British Arctic Expedition, wintered in latitude 81° 40′ north, longitude 64° 30′ west, in a well-sheltered inlet directly opposite to the winter-quarters of the Polaris. Here she lay imbedded in the ice for ten months and a half. In preparation for the long winter, a layer of snow ten or twelve inches thick was laid on the deck, but as it was found not to bind, it was mixed with ashes and water, and soon made a good macadamized road. Then snow was piled up outside the ship about fifteen or twenty feet thick. This and the layer on deck kept the warmth in the ship, and the temperature in the lower deck ranged from 48° to 56°. Between April 26th and October 16th the ship's company shot thirty-two musk-oxen, thirty-six hares, six seals, and five eider-duck—about four months' rations of fresh meat. Captain Stevenson, commander of the Discovery, considers the long winter the most enjoyable time of the whole period spent in the arctic regions, the ship being very warm and comfortable, and all hands employed in the work most interesting to themselves.

Voice of the Elephant.—According to Major Leveson, author of "Sport in Many Lands," elephants utter four distinct sounds, each of which is indicative of a certain meaning. The first is a shrill whistling noise, produced by blowing through the trunk; this denotes satisfaction. The second is the note of alarm or surprise, a sound made by the mouth; it may be represented thus: *pr-rut, pr-rut!* The third is a trumpeting noise indicative of anger; when the

animals are very much enraged, or when they are charging an assailant, this sound changes into a hoarse roar or terrific scream. The fourth sound betokens dissatisfaction or distress; it is repeated frequently when an elephant is separated from the herd, or is tired, hungry, or overloaded; it may be thus imitated: *urmph, urmph.*

NOTES.

Written, as the little sketch of "Audubon's Flower" was, where access to books was impossible, and upon the memory of a reading of twenty years ago, I fear that, in the closing part, I may have overstated. It is not meant that Audubon *named* the flower, except conceptionally, or mentally, but that he did name it so far as a truthful bit of art could do, subordinated to a scientific conscience. S. L.

Dr. Lawson Tait finds that, as a rule, the ear in women can perceive higher notes (i. e., sounds with a larger number of vibrations per second) than the ear in men. The highest limit of and ability for the human ear is somewhere between 41,000 and 42,000 vibrations per second. Very few of the persons experimented on by Dr. Tait had equal sensibility to acute sounds in both ears the right ear usually hearing a higher note than the left. The sense of direction of the sound in the human ear seems to be lost at a very much lower point than appreciation of the note. This, however, is not the case with cats.

On January 11th died Mr. Alfred Smee, aged about sixty years. He was elected Fellow of the London Royal Society at the early age of twenty-one. Among his published works were the following: "Elements of Electro-Metallurgy," "Elements of Electro-Biology," "Monogenesis of Physical Forces," "The Mind of Man," etc.

Karl Ernst von Baer, the eminent biologist, whose death occurred in November, was born in Esthonia, February 12, 1792. In 1819 he became Professor of Zoölogy in the Königsberg University. He was called to St. Petersburg in 1834, and was appointed librarian of the Academy. He led a scientific expedition to the northern shores of Russia in 1837. He wrote several works on zoölogy and botany, especially those of Northern Russia.

Wilhelm F. B. Hofmeister, Professor of Botany in the University of Tübingen, and author of several works on plant physiology and embryology, died on January 12th, at the age of fifty-two years.

The world of science has recently suffered another loss in the death of David Forbes, F. R. S., the geologist, at the early age of forty-eight years. He was a great traveler, and among his published papers may be named those on the "Relation of the Silurian and Metamorphic Rocks in the South of Norway," and on the "Geology of Bolivia and South Peru."

Blanca Peak, in Colorado, the elevation of which was determined last year by Hayden's survey, is probably the highest point within the limits of the United States. Its height is 14,464 feet above the level of the sea. There are in Colorado over fifty other peaks which rise more than 14,000 feet above sea-level.

Mr. Robert E. C. Stearns mentions, in the *American Naturalist*, two remarkable instances of vitality in snails. One snail, of the species *Bulimus pallidior*, lived for two years, two months, and sixteen days, without food, and at the end of that period appeared to be in pretty good health. Another, *Helix Veatchii*, lived without food from 1859 till 1865. Both of these species of snails are indigenous to nearly rainless regions.

There is a pretty constant increase in the decennial number of plural childbirths in the kingdom of Prussia. In the period between 1824 and 1834 this class of births amounted to 112 per 10,000 births, and the same proportion was repeated in the succeeding decennium. From 1844 to 1854 the proportion was 114 to 10,000; from 1854 to 1864, 123; from 1864 to 1874, 128. Of these plural births, the immense majority, nearly 99 per cent., were twins. Triplets were somewhat less than 1 per cent. In over 6,000,000 births there were only 79 cases of four at a birth, and one case of five at a birth.

The Atamasco Lily.—A new form of this favorite amaryllis, *A. Atamasco*, has been found in Florida by Mrs. Mary Treat. It is an earlier flower than the old form, and is larger and handsomer.

It was stated by Mr. Sidebotham, at a meeting of the Manchester Literary and Philosophical Society, that aniline colors are now much used by artists both for paintings and water-color drawings. But, as nearly all of these colors fade under the action of light, no artist who wishes his work or fame to endure can afford to employ them.

Years distinguished by a maximum of sun-spots coincide very closely, according to Prof. Fritz, of Zürich, with years of extraordinary hail-fall, or unusual average height of the great rivers.

A short time ago a number of fossil footprints, supposed to be human, were discovered in the carboniferous sandstone near Metropolis, Illinois. A physician living in that locality, Dr. Gebhart, took plaster casts of these footprints and sent a description of them, together with full details as to site, to Mr. Darwin and other naturalists. The almost unanimous verdict was, that the tracks were those of a species of *Labyrinthodon*. According to Dr. Gebhart, the animals which made these fossil tracks were most certainly bipeds.

In countries where the coffee-tree is cultivated the leaves are used to make an infusion which by many persons is held to be superior to the infusion from the berry. Hitherto they have not been an article of commerce, and the planter has studied to obtain as large a crop as possible of the berry, neglecting the leaves. But if a demand for the latter should spring up in foreign countries, the planter would find it as profitable to cultivate the coffee-tree for its leaves as for its fruit. The berry would first be secured, with a sparing use of the pruning-knife, and then the leaves would be carefully gathered and cured for exportation. The result would be in a great measure to drive out of the market the spurious compounds that now too often are sold as coffee.

It was in 1865 that the phylloxera appeared in the vineyards of the south of France; its ravages have been continued ever since. The department of Gard, which used to produce 126,000,000 gallons of wine, now yields not one-fourth as much. One commune, Castries, in the Department of Hérault, annually produced, before the appearance of the phylloxera, 3,000,000 gallons; one year later the product was 250,000 gallons; three years later the vineyards had been entirely destroyed!

A scientific journal of Paris notes the occurrence of a peculiar phase of insanity among French cooks. It is called *folie des cuisiniers* (cooks' insanity), and is due to the carbonic oxide given off by charcoal-stoves. The principal symptoms are hallucinations of sight and hearing, vertigo, oppression, and syncope. The patient generally believes himself to be the victim of persecution.

The efficacy of the alkaline sulpho-carbonates as a means of exterminating the phylloxera appears to have been demonstrated by experiments made by Mouillefert, at the instance of the Paris Academy of Sciences. It still remains, however, to devise suitable methods of employing this insecticide. "Science," says M. Mouillefert, "has accomplished its mission, and it is now for agriculture to perform its part."

Early in the present year a State Zoological Society was organized in San Francisco, with the object of collecting material for a public museum of Pacific coast rocks, fossils, ores, and all inorganic substances having a bearing on practical geology. Another purpose of the society is to promote geological research. The coöperation of mine-owners and mining-engineers on the Pacific slope is solicited by the president of the society, so as to make the proposed collection fully representative of the geology of that portion of the United States.

Between Nice and Monaco is a locality so unhealthy that the Paris, Lyons & Mediterranean Railway Company have been obliged to change every two or three months the watchman at the crossing there. Plantations of the eucalyptus have been formed at this place, and at present the same watchman has resided there for several months with his family without experiencing the least inconvenience.

On investigation, in Paris, of a case of lead-poisoning, no lead could be found in the cooking-utensils or in the food and drink of the patient. Lead was discovered, however, in a piece of a Roquefort cheese, which was enveloped in a metallic sheet, composed of 12 parts of tin, 85 of lead, and 3 of undefined matter. The conclusion drawn was, that the lead contained in the cheese was imparted to it by the envelope.

Trials have been made in Rome of a solution of chloride of calcium as a substitute for water in laying dust in streets. The results are said to be highly satisfactory. The dampness communicated to the road, instead of disappearing quickly, as is the case when water alone is used, remains for a whole week. The road continues to be damp without being muddy, and presents a hard surface, on which neither the wind nor the passing of pedestrians or horses has any effect.

Some fifty years ago two gangs of workers in a Belgian coal-mine were at variance, and one party made a fire so as to smoke out the other. The coal in the mine became ignited, and it continues to burn down to the present day. Efforts have been made again and again to extinguish the fire, but in vain. Mr. Richard P. Rothwell, editor of the *Engineering and Mining Journal*, who mentions this case in a paper on fires in mines, cites a few similar instances from the history of mining in the United States of seams of coal burning for several years—as the Summit Hill Mine, near Mauch Chunk; the Greenwood Company's mine, near Tamaqua; and others in Schuylkill, Carbon, and adjoining counties of Pennsylvania. Some of these mines have been burning upward of twenty years.

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